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Jamie Jirout & David Klahr

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Questions – And Some Answers – About Young Children's Questions

Jamie Jirout[a] and David Klahr[b]

[a]University of Virginia; [b]Carnegie Mellon University

ABSTRACT
Question asking plays a fundamental role in learning, and the cognitive development literature contains many studies of specific types of question-asking skills. However, little is known about the developmental course across different aspects of question asking, of which we explore: (a) the ability to ask questions that enable children to solve a specific problem, (b) the ability to ask questions that will increase general understanding about a topic, (c) the ability to recognize the relevance of information yielded by another person's answer to a question, and (d) children's general levels of curiosity. The current study includes four tasks assessing preschool through first-grade children's curiosity and performance on the three different types of question-asking tasks listed above. We observed significant development between kindergarten and first grade in children's question-asking and significant correlations among the different question-asking tasks. Children who generated more questions for problem solving were better at recognizing effective questions, and generating questions for learning was related to generating problem-solving questions. Both the ability to recognize effective questions and to generate questions for learning were positively correlated with our measure of children's curiosity. The results and implications are discussed for understanding the development of question-asking skills and the role of curiosity as a fundamental motivator of children's question asking.

> If I had an hour to solve a problem and my life depended on the solution, I would spend the first 55 minutes determining the proper question to ask, for once I know the proper question, I could solve the problem in less than five minutes.[1]

Developing children's question-asking skills is an important educational goal (Common Core State Standards, National Governors' Association, 2010; National Research Council, 2012). Questions can be expressions of curiosity, and question-asking proficiency has obvious consequences for academic performance and learning (Berlyne, 1954; Chouinard, 2007; Courage, 1989; Dewey, 1910; Haden, Cohen, Uttal, & Marcus, 2015; Kidd & Hayden, 2015; Redfield & Rousseau, 1981; von Secker, 2002).

Although question asking plays a crucial role early in the course of children's cognitive development (Chouinard, 2007), much of the research on how questions influence learning in school has been conducted with mid-elementary through college-age students (Chin &

CONTACT Jamie Jirout Jirout@virginia.edu University of Virginia, Charlottesville, VA 22903

[1]Quote commonly attributed to Albert Einstein 1879–1955, possibly from *Physique, philosophie, politique* (Einstein & Balibar, 2002).

Osborne, 2008, though see Ronfard, Zambrana, Hermansen, & Kelemen, 2018), and investigations typically assess children's use of questions in either a learning context *or* a problem-solving context, but not in both contexts. Consequently, little is known about the developmental relationship between these two distinct types of question-asking contexts. In this paper, we investigate the early developmental course of three different aspects of question asking: (a) the ability to ask questions that will enable children to solve a specific problem, (b) the ability to ask questions that will increase children's general understanding about a topic, and (c) the ability to recognize the relevance of information yielded by another person's answer to a question. Each of these types of question asking involves a surprisingly complex set of underlying cognitive processes – as we indicate below in a cognitive task analysis (Chipman, Schraagen, & Shalin, 2000) that articulates the required cognitive processes for each type of question-asking task. In addition, because question asking is usually a manifestation of children's intrinsic curiosity, we also provide an assessment of the relation between children's individual levels of general curiosity and their performance on the three question-asking tasks.

Children's question asking

Observational studies of very young children's conversations with their parents reveal a high frequency and broad range of questions, in some cases exceeding 100 questions per hour (Chouinard, 2007). And much infant behavior – such as gesturing, looking, and vocalizing, with the expectation of an adult response – can be interpreted as evidence of a form of questioning (Begus & Southgate, 2012). In general, effective question asking can promote high-quality language interactions that produce positive developmental outcomes (Kurkul & Corriveau, 2018; Ronfard et al., 2018), but this is unlikely to happen unless the child's question unambiguously identifies the desired information, which in turn produces an answer – usually from a knowledgeable and trustworthy source – such as an adult (Mills, Legare, Bills, & Mejias, 2010). In observational studies, it is often difficult to determine the effectiveness of a child's question because the child's underlying goal for asking that question is not known, making it unclear whether or not the adult's response was informative. Indeed, the child's goal in asking a question may sometimes be simply to attract adult attention, rather than to elicit information (Beyer, 1940). Another type of question-asking proficiency is the ability to gather information, as when a child has a specific knowledge gap and generates a question that successfully elicits information that helps to close that gap. This type of question can promote problem solving, as well as learning and understanding, and is the focus of the current study. Past studies have found that even preschool and early-elementary age children are capable of asking effective questions for solving simple problems (e.g., Chouinard, 2007; Mosher & Hornsby, 1966) and for understanding (Callanan & Oakes, 1992; Greif, Kemler Nelson, Keil, & Gutierrez, 2006). These children also have some capacity to evaluate the relative effectiveness of questions, although not as well as adults (Ruggeri & Feufel, 2015). Our study extends this prior body of work by investigating the relations across these different types of question-asking skills, along with the relation between the different question tasks and curiosity. We begin with a brief review of the literature related to the development of the specific question-asking skills investigated in this study (see Ronfard et al., 2018, for an extensive review).

Questions for problem-solving

One frequent topic of research on question asking is the ability to use questions in structured problem-solving tasks, in which children ask categorical or constraint-seeking questions (Ronfard et al., 2018). A common method of assessing children's ability to ask these effective questions is to engage them in a referential task, analogous to the "20 Questions" game, in which their goal is to determine the identity of a hidden object by asking a series of yes/no questions (e.g., Chouinard, 2007; Cosgrove & Patterson, 1977; Courage, 1989; Mills et al., 2010; Mills, Legare, Grant, & Landrum, 2011; Mosher & Hornsby, 1966; Ruggeri & Feufel, 2015). In these tasks, a question is effective to the extent that it eliminates distractors from the array, e.g., by asking a categorical question related to features of the stimuli.

Prior research has revealed that even preschoolers have the rudimentary ability to ask effective constraint-seeking questions if the task is simple enough, and that this ability improves across development. For example, Chouinard (2007) found that when preschool-age children were given the opportunity to ask constraint-seeking questions such as "is it an animal?" – before guessing which of two items (e.g., a picture of either a ball or a cat) was hidden in a box, they were correct on five of six trials. However, on slightly more challenging referential problems (e.g. four clowns differing by color and facial expression, rather than a cat vs. ball), preschoolers had difficulty using constraint-seeking questions effectively (Cosgrove & Patterson, 1977). With more challenging stimuli, and without specific training, successful use of constraint-seeking questions doesn't appear until elementary school. However, it is possible that children are *capable* of asking these questions but don't unless encouraged to do so by the task design (Legare, Mills, Souza, Plummer, & Yasskin, 2013; Ruggeri & Lombrozo, 2015). We explore this issue in our analysis of children's ability to use questions for solving problems.

Questions for learning

Questions facilitate learning when they solicit information, explanation, or elaboration in order to solve problems or to better understand concepts, yet these types of questions are often difficult for children to ask (King, 1991; Palinscar & Brown, 1984). The generation of higher-level questions, such as those soliciting explanation or elaboration to solve complex problems, rarely occurs even in older children unless explicitly taught (King, 1991). Nevertheless, prior research has found that children as young as 2- to 4-years-old can ask topic-appropriate questions seeking basic information of what something is called, or what it does (e.g., Greif et al., 2006; Kemler Nelson, Egan, & Holt, 2004), though the majority of preschool-age children's questions do not go beyond this type of "fact" question (Chouinard, 2007). It is likely children are curious about more complex concepts, but may not think to ask or know how to frame questions to gather that information, or perhaps more frequently ask lower-level questions as a result of having less prior knowledge (Miyake & Norman, 1979; Ram, 1991). The current study includes a question-asking task to assess children's questions for learning.

Evaluating the effectiveness of questions

Three overarching skills for acquiring knowledge by asking an effective question include (a) the ability to formulate and produce the question, (b) the ability to identify a knowledgeable source to whom to direct the question, and (c) recognizing whether or not the response to the question contained the desired information (Ronfard et al., 2018). One way these skills have been studied is by comparing questions children choose to ask across options that differ in the amount of information they can provide. For example, second-graders' use of effective questions on a 20-questions style "Guess Who" game increases with experience (Nelson, Divjak, Gudmundsdottir, Martignon, & Meder, 2014). Children around this age choose to ask more effective questions from a range of options at higher rates than chance (Ruggeri & Feufel, 2015). Children are able to estimate the potential value that might be yielded by an answer to different questions that they might ask, with 2nd-5th graders and adults using questions to identify the correct explanation for a described event from several possibilities (Ruggeri & Lombrozo, 2015). Moreover, these studies show that older children can also evaluate the level of effectiveness of a question. Although this ability has not yet been studied in young children, Samuels and McDonald (2002) found that fourth-grade children could choose diagnostic over non-diagnostic questions to identify a target object from other options, where the diagnostic question corresponded to a difference among objects and the non-diagnostic corresponded to a shared feature. And even first-graders can determine whether hypothetical information could answer a question (Koerber, Mayer, Osterhaus, Schwippert, & Sodian, 2015; Sodian, Zaitchik, & Carey, 1991). The current study assesses whether children can categorize question effectiveness (helpful vs. not helpful).

Question-asking processes

Ronfard et al. (2018) propose a general, and widely applicable model of question asking that includes three primary stages: initiation, formulation, and expression. Initiation involves the understanding that there is some information attainable by asking a question. Formulation involves identifying the information needed, and phrasing a question requesting that information. Expression is deciding whether or not to ask the question, considering both whether there is a reliable source of information and if the context is appropriate for asking a question. These three stages are followed by evaluation of the response received, which determines whether the sequence will end, a question will be restated, or a new question will be asked. In this paper, we elaborate the major components of the Ronfard, *et al.* model, as logically determined by the nature of our question-asking assessment procedures. We present a detailed cognitive task analysis – CTA – (Chipman et al., 2000) that focuses on the micro-structure of each of the three question-asking tasks used in the present study, described with the task methods. The three CTAs articulate the sequence of component processes that are logically required by the three different question-asking tasks.

Questions as an expression of curiosity

In addition to children's use of questions to solve particular problems or to acquire specific information, questions can be more general information-seeking tools that are used in the service of a child's curiosity (Chin & Osborne, 2008; Jirout & Zimmerman, 2015; Luce & Hsi, 2015). Curiosity has been generally characterized as a basic desire for information (Berlyne, 1954), and more specifically characterized as a response to an information gap, with a moderate level of uncertainty – neither too much nor too little – leading to the greatest curiosity (Jirout & Klahr, 2012; Loewenstein, 1994). People are most likely to explore in situations where a moderate level of uncertainty is present (Litman &

Jimerson, 2004; Loewenstein, 1994). However, in addition to these situation-dependent levels of effort to reduce uncertainty, there are also individual differences in the preference for the optimal amount of uncertainty that will trigger the most search for uncertainty-reducing information (Jirout & Klahr, 2012). Thus, it is possible to assess a more stable level of individual uncertainty preference, and this preference has been shown to relate to learning behaviors such as competence motivation and persistence (Jirout & Klahr, 2012). Curiosity-driven question asking provides a potential way to acquire missing information, and Luce and Hsi (2015) suggest a strong influence of context on the expression of curiosity and questioning. For example, increased knowledge through question asking can support increased interest in a topic and further questioning and (Hidi & Renninger, 2006; Minigan, Westbrook, Rothstein, & Santana, 2017), and Dewey (1910) suggests that question asking is a higher level of curiosity than more simple exploration. Thus, it is of interest to explore how different types of questions assessed in the current study relate to one another and how this variable expression of curiosity relates to a more stable view of curiosity.

Current study

We know of no previous study that has assessed children's question-generation and question-evaluation abilities across a battery of related, albeit distinct, tasks. The goal of the present study is to extend prior work by (a) investigating effective question asking across tasks, (b) assessing the early development of children's ability to recognize and generate effective questions, and (c) determining the relationship between curiosity and different aspects of children's question-asking competence.

We hypothesized that young children would generate and recognize effective questions, and that these abilities improve with age. We also expected to find a correlation between children's ability to generate effective questions and to recognize them. Specifically, we expected tasks involving verbalizing questions to relate (i.e., questions generated for problem solving and questions generated for learning), and tasks involving similar goals (i.e., problem solving) to relate (i.e., questions generated for problem solving and categorizing effectiveness of questions). Finally, we expected that curiosity would relate to performance on the different types of question-asking tasks, as children who are more curious likely have more experience in asking questions, and consequently have had more opportunities to assess the effectiveness of their questions.

Methods

Participants

Participants were 115 children (56% female) ranging in age from 4.3 to 7.5 years, with a mean of 5.1 years (SD =.75): 26 preschool children from five different suburban daycare centers,[2] 49 kindergarten and 40 first-grade children from three classes in each grade of two suburban charter schools. One child was excluded due to lack of motivation and understanding of tasks; some children did not complete all tasks due to time constraints or

[2]Due to relatively low response rates from the daycare centers, this sample size for our pre-school participants is less than desirable. However, the variance in pre-school scores turned out to be no greater than the variance from the other grade levels.

experimenter error (seven children did not complete the questions for learning or were outliers, N = 107; 10 did not complete the questions for problem solving, adjusted N = 104; and 10 did not complete the recognizing effective questions task, adjusted N = 104). Participants' ethnic and socio-economic distributions were representative of the local populations, which varied by school: 63%-83% of the children qualified to receive free and reduced lunch. Parental consent was received for all participants and stickers or pencils were given as compensation for participation.

Design

A cross-sectional (three grades), within-subject design was used to compare the development of, and relationships among, the different question-asking tasks and with curiosity. Children were tested individually in their school, and recordings were coded at a later time.

Measures

Every child was presented with four distinct tasks: (1) a 20-questions type task in which children use questions to identify a target item from an array, which involved using questions to acquire specific needed information to solve a problem; (2) an open-ended question-generation task, which involved generating questions to learn anything children choose to ask about a specific, given topic; (3) a question-effectiveness evaluation task, which involved identifying whether or not given questions provide information useful in solving a problem; and (4) a curiosity assessment task, which involved measuring the level of uncertainty children prefer to explore. Each task is described below, and question-asking tasks include a Cognitive Task Analysis.

Questions for problem solving: 20-questions task

Children were told that the object of this game was to identify a target picture on each of five turns with two 8-item arrays of pictures (see Figure 1). For each array, every picture displayed the same type of object, but with differentiating features. For example, a bee

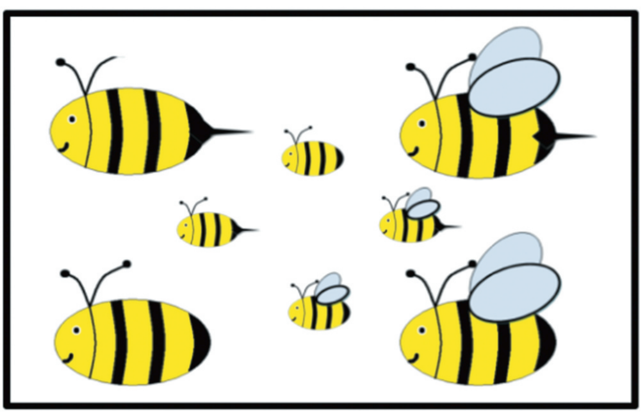

Figure 1. Example stimuli from 20-questions task, in which children ask constraint-seeking questions to eliminate distractors and identify the target picture.

array differed in three dimensions: four had wings, four did not; four were big, four were small; four had a stinger, four did not (see Figure 1). Children were told:

> We are going to play a listening-and-asking game. We have a set of pictures that are the same. See, these are all bees. Here's how we will play. I will tell you about one of my pictures. I will call it the special one. Your job is to find the special picture. Sometimes I won't tell you enough about the special picture and you won't be sure which one I mean. If that happens, you can ask me questions to help you find it." (Display first array)"Look at these pictures of bees. Some bees are big, and some are small. Some bees have wings, and some do not. Some bees have a stinger, and some do not. (with pointing)

For each array, children were given two trials with no information about the target (e.g., "The special one is a bee"), and one trial each with one, two, or three dimensions given (e.g., "The special one is a small bee" and "The special one is a big bee with wings and a stinger"). The different trials (i.e., no dimensions given, one dimension given, etc.) were randomly ordered for each array, with the same order used for all participants. Four different arrays were used, differing on similar dimensions: bees, leaves, worms, and clouds. The pair of arrays that was used for each child was randomly selected to be either bees and leaves or worms and clouds, and the presented pairs were of similar difficulty (based on pilot testing). All arrays were presented in color on laminated 8.5" x 11" white paper with similar spatial layouts so that the differences were relatively grouped as much as possible across the dimensions.

Cognitive task analysis of 20-questions task. After the child receives instructions, the steps of this task are as follows (also, see Figure 2):

(1) *Uncertainty recognition*: the realization that there is more than one possibility for the target picture, and that more information is needed to determine which of the eight pictures is the target (Courage, 1989, refers to this process as "message appraisal").
(2) *Evaluation of information*: identifying any information given about the target (the amount of information given to the child varies on each trial).
(3) *Comprehension monitoring* (Whitehurst & Sonnenschein, 1985): application of given information to eliminate non-referents from the set of possibilities.
(4) *Identifying needed information*: identification of characteristics that can be used to eliminate non-referents (Whitehurst & Sonnenschein, 1985).
(5) *Question formation*: could use an inefficient guessing strategy, or an efficient strategy of asking categorical questions to narrow down the possibilities, for each question.
(6) *Reevaluate information* and comprehension monitoring to apply new information to eliminate non-referents.

This process is repeated until only the target picture remains. If children fail at any of these steps, they may resort to guessing pictures individually to eliminate all but the target.

Questions for learning: open-ended generation task

Children heard a brief introduction and then watched a minute-long video on a laptop computer about bees from the show "Sid the Science Kid". Instructions were:

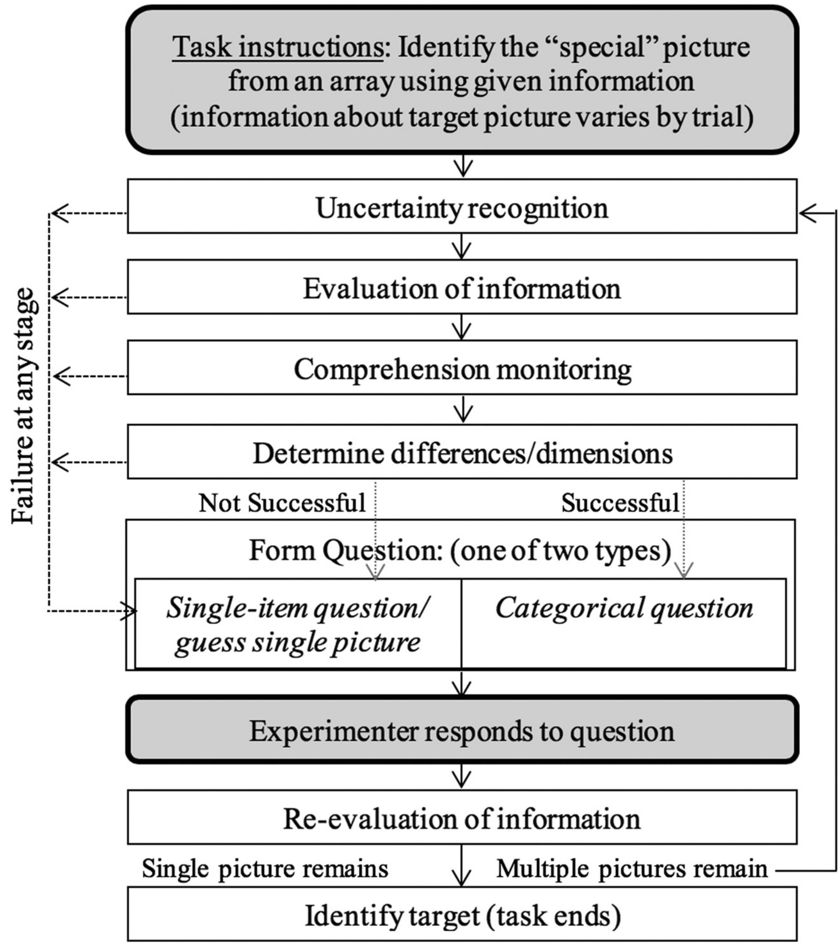

Figure 2. Referential task: Cognitive task analysis. Children must identify a target picture from an array. An inefficient strategy is to guess one item at a time, until only the target picture remains. The efficient strategy is to eliminate non-referents using categorical questions.

> That was a fun song about bees! After watching that movie, can you think of any questions that we could ask to learn more about bees? I will keep track of your questions using my recorder, so that I can go home and find the answers to put them in a book I am making. So, what do you think- do you have any questions?

Children's questions were not answered directly, instead, they received a non-informative, but supportive, responses such as, "Hmm, that's an interesting question!" Previous research has found that almost half of the questions children ask during observations are "follow-up" questions, after receiving answers to an initial question (Chouinard, 2007). Children were told that their class would receive a copy of the book being made so they anticipated that they would ultimately receive the answers to their questions, and there was no indication of a difference in initial questions asked during pilot tests with a version of the task that *did* include answering children's questions. If children did not respond to prompt within five seconds, they were prompted again. The task ended when a child responded 'no' to the prompt, either verbally or by shaking his or her head, or had no response after prompts. Responses were coded as either explanatory questions, fact questions or non-questions.

Cognitive task analysis of open-ended question generation. After the child receives instructions, the steps of this task are as follows (also, see Figure 3):

(1) *Comprehend the goal*: Child understands that he/she is being asked to generate a question about the given topic. If the child fails to understand this goal, then she/he will typically (a) say "I don't know" or "I have no questions", or (b) provide a verbal non-question response with information about the topic, or (c) fail to respond at all. If the child does comprehend the goal, he/she proceeds to the next step.
(2) *Uncertainty recognition*: identifying what is known and unknown and/or what can be learned (referred to as "anomaly detection" by Graesser, Person, & Huber, 1992).
(3) *Question formation*: asking a question that requests information about the topic (what Graesser et al., 1992, labels "question articulation").

Our criteria for scoring the child as having asked a question include one or more of the following: 1) an appropriate question stem, 2) raised intonation signifying a question, or 3) an explicit statement of desiring to know some information. If none of these is met, then the response was considered a *non-question*. Once the child finishes responding (indicated by five seconds of no response), the experimenter gives generic feedback (e.g., "that is interesting!") and prompts the child again ("can you think of any (more) questions . . ."), with up to three prompts given. Children were permitted to continue asking questions unprompted until indicating that they were done.

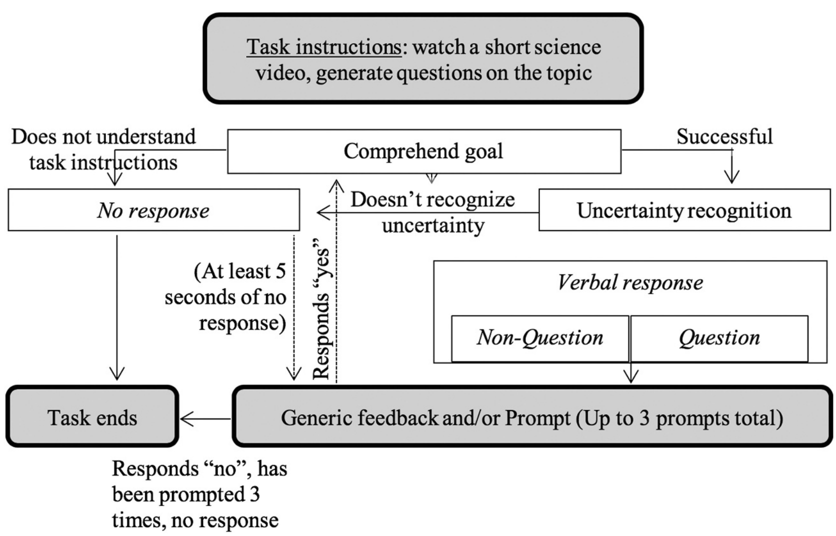

Figure 3. Generation task: Cognitive task analysis. Children generate questions after watching a short science video. Some children give no verbal response, some respond verbally but do not ask questions, and some successfully generate questions.

Evaluating question effectiveness: discrimination task

Children were told a story about a child who wanted to use questions to gather information and discover the identity of an animal living in the woods. Eight questions were presented on laminated cards with color images related to the question – four helpful questions to learn what type of animal it is (e.g., what does the animal eat?), and four not-helpful questions (e.g., what is Chris's favorite animal?). After the instructions, children were reminded of the goal:

> Remember, Chris is exploring to find out what the mystery animal is by asking questions and finding the answers. Some questions Chris asked were helpful to learn what kind of animal it is, but some questions were not helpful. I am going to tell you each question that Chris asked and the answer he found, and I want you to tell me whether the question is helpful, or not helpful, okay?

Question cards were presented face-down, and children selected one at a time for the experimenter to read and answer (Figure 4). The child was then prompted to place the question in either the "helpful" or "not helpful" box, large rectangle outlines on separate 8.5" x 11" laminated papers with labels. Initial instruction was given for using "helpful" and "not helpful" charts to categorize the questions, and the helpful chart was always presented on the left. Children were permitted to place any number of questions in either of the boxes,

Figure 4. Image of the discrimination task, in which children categorized questions as either helpful or not helpful with respect to gathering information about a mystery animal.

and could move the questions from one box to another at any time during the task. At the end of the task, children lifted a flap to find out what the animal was.

Cognitive task analysis of the discrimination task. After the child receives instructions, the steps of this task are as follows (see Figure 5):

(1) *Uncertainty recognition*: recognition that there is an unknown, hidden animal.
(2) *Comprehend the overall goal of the discrimination task*: to categorize questions as helpful or not helpful with respect to whether or not their answers could yield information about the type of animal that is unknown/hidden.
(3) *Experimenter reads the question* child chooses (i.e., "What does the animal eat? … The animal eats berries"). Child hears the question and its answer.

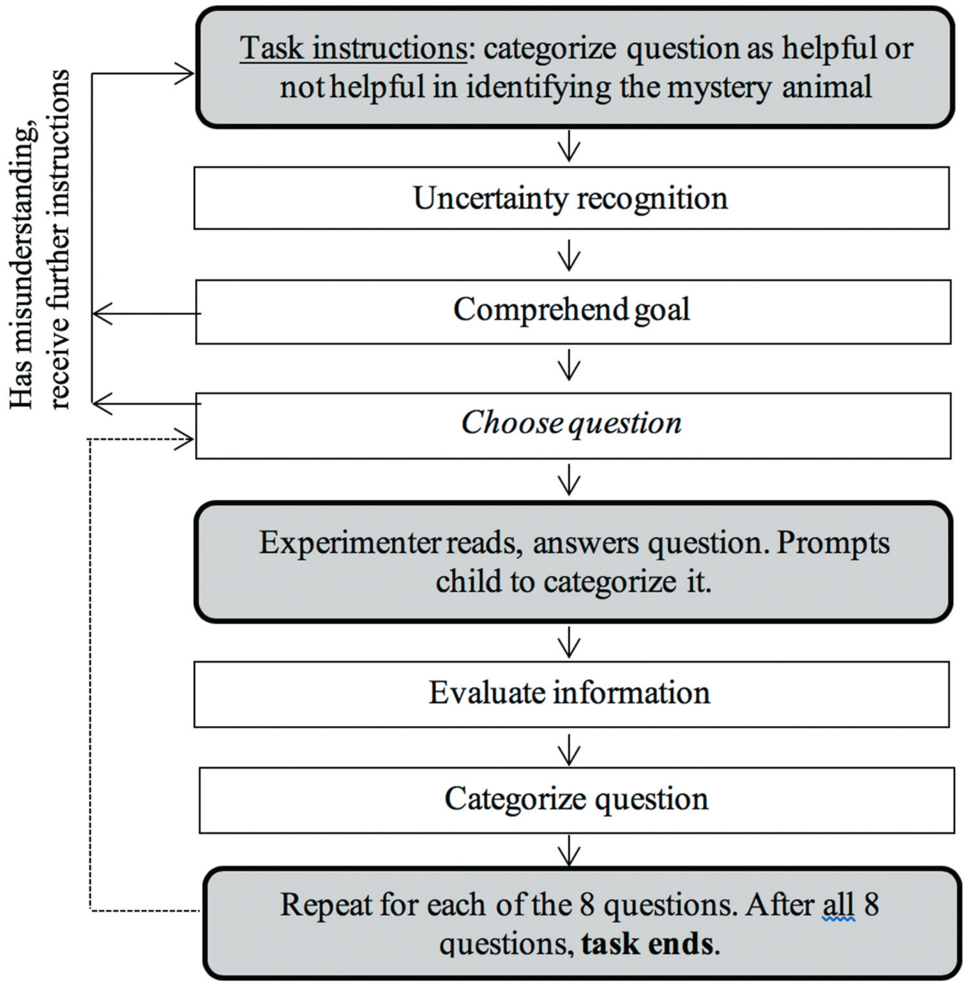

Figure 5. Discrimination task: Cognitive task analysis. Children categorize questions as helpful or not helpful in learning about a mystery animal.

(4) *Evaluate the information*: determine whether question and its answer provide information about the mystery animal. If they do, the child *further evaluates* the information to determine whether it provides information about the type of animal
(5) *Categorize* the question and its answer: they are *not helpful* if they fail to provide information about the type of animal, and *helpful* they do.

This process is repeated for all eight questions in the task.

Curiosity task

Curiosity was assessed using a computerized adaptive exploration task that yielded a measure of children's preference for uncertainty (Jirout & Klahr, 2012). Children played an interactive computer game that presented them with a series of 18 forced-choice trials. On each trial, such as the one shown in Figure 6, two alternatives indicated different amounts of information about what might be behind each of two windows. A child's choice across each set of three trials with the same uncertainty comparisons determined the uncertainty level of the subsequent trials. The procedure "sorts" each child to a final state that provides an index of each child's preference for uncertainty – or curiosity – as operationally defined in Jirout and Klahr (2012).

Procedure

Parental consent was obtained for all participants, and teachers introduced the researchers to each class before children's assent was collected by inviting individual children to play. If the child agreed, then the experimenter led the child to a table located in a nearby classroom or hallway, cafeteria, or library. Children participated in two sessions, counterbalanced and within a week of one another, with one including the questions for problem solving and for

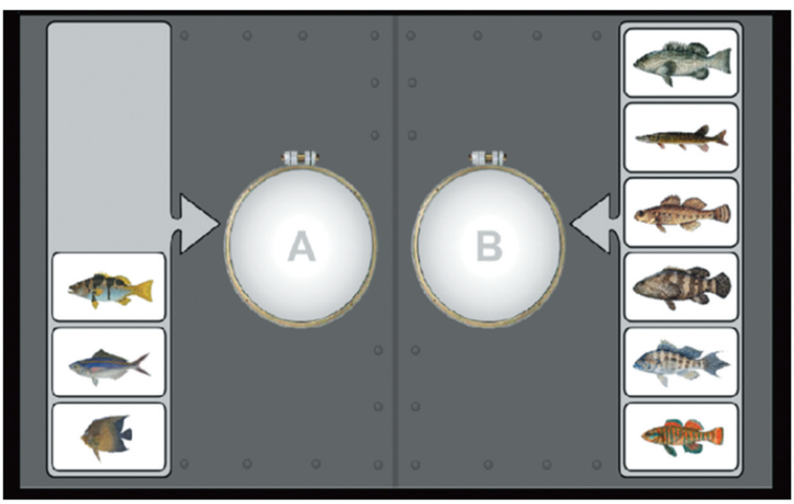

Figure 6. Screenshot from the curiosity measure, in which children chose to explore between different levels of information to determine their preference for uncertainty.

recognizing effective questions, and the other including the questions for learning task and the curiosity task.

Data coding

All data were recorded for later coding and analysis. Scoring for each task was as follows:

- Questions for problem solving: (20-questions task) We assessed the effectiveness of their strategies by coding categorical (more effective) questions as any question that had the potential to eliminate more than one possible item from the array, and guesses as a child naming or pointing to a single picture. Performance was analyzed as 1) the proportion of categorical questions to total questions+guesses,[3] and 2) whether the child asked any categorical questions. By design, all children successfully solved each trial on this task.
- Questions for learning: (Open-ended question generation) Responses were coded as questions vs. non-questions and for question type, and were analyzed as 1) total number of questions asked, with separate analysis of "fact/identification" questions and "explanatory/understanding" questions, and 2) whether children asked any questions. Inter-rater reliability was assessed for 30% of the data, and exceeded 90% exact agreement in codes (e.g., coding of questions vs. non-questions, fact vs. explanatory questions), with Cohen's K = .71 for questions/non-questions, and K = .83 for fact/explanatory questions.
- Recognizing effective questions (Discrimination task): Accuracy was coded as correct placement of a question in the appropriate bin (e.g., helpful or not helpful) based on the question providing information about the mystery animal or not. Performance was analyzed as 1) overall accuracy of categorization, 2) accuracy by those categorized as helpful and not helpful separately (e.g., if five questions labeled as helpful, with the four actually helpful questions included, accuracy of helpful questions would be 80%).
- Curiosity: The exploration game provides a score based on the total amount of uncertainty explored throughout the task, with the number of possibilities on each turn summed across the 18 trials. For example, if a child chose to open a window with two possibilities of what would be found, the child would receive two points for that trial.

Results

We begin by reporting children's performance on each of the question-asking tasks and the developmental trends on those tasks. We then present the relations among the question-asking tasks and between each question task and the curiosity task, followed by exploratory tests of developmental trajectories for the different question-asking tasks.

[3]We collapsed across all trials of this task for analyses. In response to a reviewer's question, we also re-ran analyses using only trials where children were given no information about the target picture and all results remained the same, with trials with no information given correlating to scores across all trials at r =.95 for guessing questions, r =.97 for categorical questions; p values <.001).

Question-asking performance and development

Questions for problem solving

Across the five trials in each of the two sets, children could potentially identify the target with a total of nine categorical questions, or 23 (non-redundant) guessing questions, or some combination of both; sometimes, however, children repeated questions and/or guessed pictures that had already been eliminated with previous questions or guesses, increasing the total number of guesses used. Averaged across age, children asked 3.2 (SD = 3.4) categorical questions and 19.3 (SD = 8.4) guessing questions. No differences were found between the different arrays. The data were not normally distributed (all p values <.05 on the Shapiro-Wilk test of normality), with many children asking no or few categorical questions. As a result, non-parametric tests of group differences were used for all analyses, including both the Kruskal-Wallis test of distribution differences and a test of median differences, controlling for all pairwise comparisons in SPSS. Consistent with our hypothesis, differences among age groups in categorical and guessing questions asked were significant on both tests (p values all <.001; see Figure 7 for means and SDs). First-grade children asked significantly more categorical questions, significantly fewer guessing questions and total questions, and had a significantly higher ratio of categorical to guessing questions than both preschool and kindergarten children (all p values < .001); preschool and kindergarten children did not differ across these four variables (all p values >.5).

Children who had a ratio of categorical to total questions over .75 were considered to be at "ceiling" (9.6% of children reached this level – see Table 1 for average ratios and percentages at ceiling by grade). Chi-square tests revealed that significantly more first graders asked at least one categorical question, and were more likely to be at ceiling than both preschool and kindergarten children (all p < .01); with no difference between kindergarten and preschool children (all p > .3).

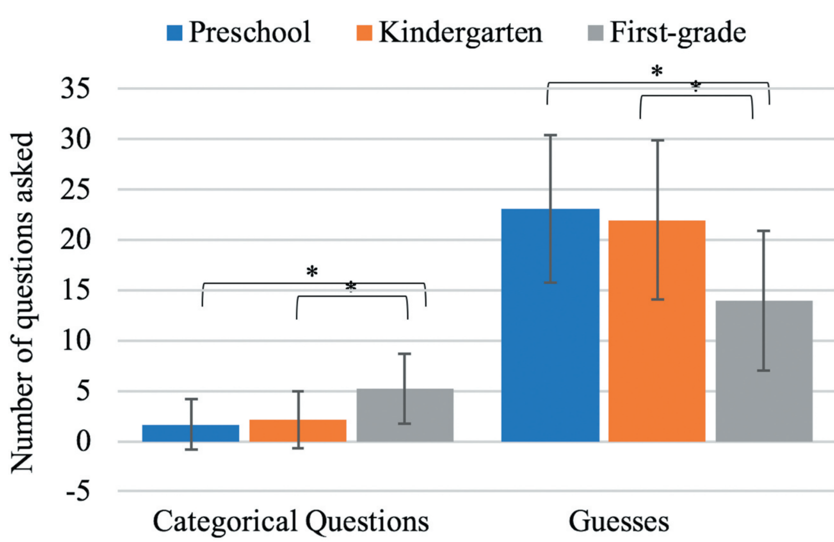

Figure 7. Means and SDs of questions on problem-solving (20-questions) task.

Table 1. Whether children asked any questions on the problem solving (20-questions) and learning (open-ended generation) tasks.

	Questions for problem solving		Questions for learning	
	% ask 1+ Cat. Q	% at Ceiling	% ask 1+ Qs	% at Ceiling
Preschool (n = 26) M =	42.3	0.0	2.7 (2.2)	42.3
Kindergarten (n = 38)	38.5	4.1	3.5 (3.4)	46.8
1st Grade (n = 39)	87.2	22.5	4.0 (3.0)	87.5
All Children:	57.7	9.6	3.5 (3.0)	60.2

Questions for learning

Recall that, on this task, children were asked to pose questions after watching a short science video. Children asked an average of 3.36 questions (SD = 10.33); however, this result was highly skewed by two outliers (26 and 78 questions). With outliers removed (here and for subsequent analyses), the mean number of questions asked per child was 1.77 (SD = 2.19); (large numbers of low and zero scores skewed the distributions), out of an average of 3.45 (SD = 3.02) total responses (including both questions and non-questions). There was no difference between fact questions (mean = 1.05, SD = 1.76) and explanation questions (mean = 0.71, SD = 1.31)(p = .10). Because the data were not normally distributed (all p values <.05 on the Shapiro-Wilk test of normality), non-parametric tests of group differences were used, including both the Kruskal-Wallis test of distribution differences and a test of median differences (however, means and SDs are presented in Figure 8). There was no effect of grade on children's total number of verbal responses (including both questions and non-questions) (p = .15), but the number of questions asked did differ among grades (p < .001). As expected, first-grade children asked more questions than preschool children (first grade = 2.82, SD = 2.1, preschool = 0.81, SD = 1.3, p < .001) and kindergarten children (kindergarten = 1.45, SD = 2.1, p < .01). Preschool and kindergarten

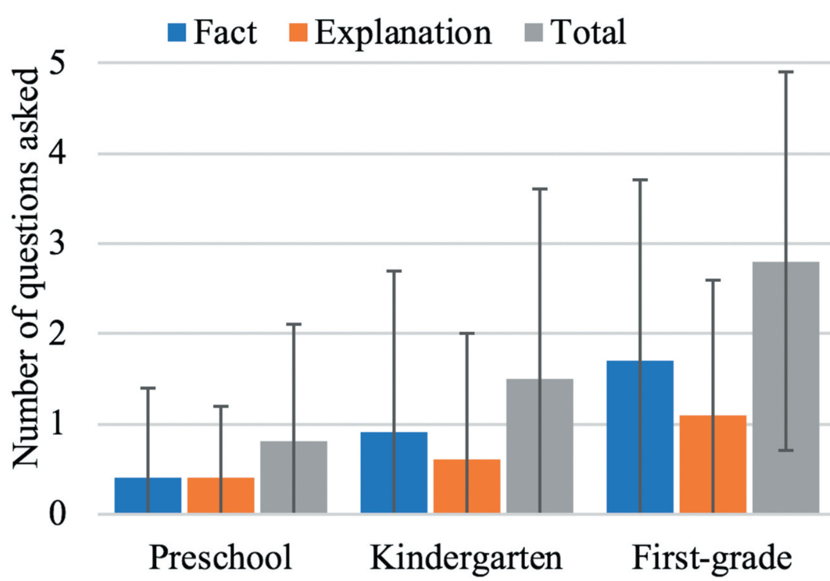

Figure 8. Questions asked for learning (open-ended generation) task performance. All differences between first grade and other grades significant; other differences not significant.

children's means did not differ significantly (p = .21). There was also a significant effect of grade on the difference in fact and explanation questions asked (p values = .001 and .02, respectively (See Figure 8 for means and SDs), with the same pattern of first-grade children more likely to ask at least one question and outperforming both preschool and kindergarten children for fact questions, and preschool children for explanation questions (all p values < .05).

Recognizing effective questions – discrimination task

In categorizing questions and answers as "helpful" or "not helpful", children's accuracy was 4.71 (SD = 1.9) out of eight (see Table 2 for means and SDs by age). Children correctly classified 2.63 (SD = 1.2) of the four helpful questions as being helpful, but only 2.09 (SD = 1.2) of the unhelpful question as unhelpful. Total score and total helpful score were significantly different from chance response using a one-sample t-test (p values < .05). Responses were biased toward "helpful" across all questions (4.54 questions labeled helpful, and 3.46 as not helpful; p < .001), so we analyzed the correct proportion of responses within helpful and not helpful questions. Specifically, of the questions that children classified as helpful, 59% were, in fact, helpful. Of questions that children identified as not helpful, 63% were, in fact, not-helpful (both significantly better than chance, and significantly different from each other, p values < .05), indicating that children were sensitive to questions' helpfulness and non-helpfulness. This was confirmed using d-prime analyses (hits = *correct helpful*, correct rejections = *correct not helpful* (p < .05).

Group differences in accuracy were analyzed using ANOVAs with post-hoc analyses (using Bonferroni corrections) for age group (see Table 2 for all means and standard deviations). As expected, the differences in accuracy among age groups for total score, helpful questions, and not helpful questions were significant (p values = .008, .034, and .003, respectively). First-grade children scored significantly better than kindergarten children (p = .003) though the difference from preschool children was not significant (p = .095) on the total recognizing effective questions score. First-grade children scored significantly higher on the helpful questions than kindergarten children (p = .045) and both kindergarten and preschool children on the not helpful questions (p = .003 and .040, respectively). Preschool children categorized significantly more question as helpful than both kindergarten and first-grade children (p = .015 for effect of age, p = .028 for difference from both kindergarten and first-grade children, who were not different from each other, p = 1.0). Because preschool children categorized more questions overall as helpful, skewing their scores on the correct helpful questions, we assessed the accuracies of helpful and not helpful questions calculated by the proportion of correct responses to total responses, which showed a significant effect of age for both (p helpful = .022, p not helpful = .004), with first-grade children having greater accuracy than kindergarten children for both helpful

Table 2. Performance on the question discrimination task (Means and SDs by grade).

	Total	Helpful	Not Helpful	Total labeled Helpful	Corrected Helpful	Corrected Not Helpful
Preschool	4.4 (1.5)	2.8 (1.1)	1.6 (1.2)	5.2 (1.8)	55.2% (19.5)	55.7% (33.0)
Kindergarten	4.2 (2.0)	2.2 (1.2)	1.9 (1.1)	4.3 (1.2)	52.6% (25.5)	50.6% (29.0)
1st Grade	5.4 (1.9)	2.9 (1.1)	2.6 (1.0)	4.3 (1.0)	66.7% (23.4)	72.1% (27.5)

Corrected values based on percentage correct of those categorized as helpful and not helpful.

(p = .026) and not helpful questions (p = .006), and greater accuracy than preschool children for not helpful questions (p = .046, helpful p = .158. Preschool and kindergarten differences both p = 1.0).

Relations among question-asking tasks, between curiosity and question asking

Performance on tasks with similar cognitive demands was predicted to be related: questions for problem solving and for learning tasks both involved addressing uncertainty with verbal question generation, and questions for problem solving and recognizing effective questions tasks both involved identifying effective questions related to resolving uncertainty for a specific problem. As expected, the ratio of categorical (effective) questions to total questions asked for problem solving was significantly correlated with the total number of questions children generated for learning, $r(96) = .29$, $p < .01$. Also as expected, the ratio of categorical (effective) questions asked for problem solving correlated with total score on the recognizing effective questions task, $r(102) = .426$, $p < .001$. The correlation between recognizing effective questions and asking questions for learning was not significant (p = .334).

As predicted, children's categorization of helpful and not helpful questions on the recognizing effective questions task was positively correlated with total uncertainty explored on the exploration game (curiosity) (total score, $r = .341$, $p < .001$; helpful questions, $r = .236$, $p = .02$; not helpful question, $r = .412$, $p < .001$). Surprisingly, the total uncertainty explored (curiosity) did not significantly correlate with the number of questions children generated for learning ($r_s = .144$, $p = .101$), possibly because of the high number of children asking no questions, or for problem solving ($r = .108$, $p = .215$). However, high and low-curiosity groups, created using a median split, did differ for questions asked for learning, with high curious children asking more questions than low curious children, means = 2.20 (.33) and 1.35 (.24), respectively (p = .003), and this difference remained when we included only children who gave any verbal response (p = .021) and when we included only children who asked at least one question (p = .043). The difference in total responses was not significant (p = .417). Similarly, high curious children had significantly higher scores than low curious children on recognizing effective questions, means = 5.13 (.273) and 3.98 (.218), respectively (p = .003). There was no difference between high and low curious groups' scores on the questions asked for problem-solving task, means = .28 (.04) and .26 (.04), (p = .765).

Exploratory analyses: developmental trajectories of question-asking ability

To explore the developmental course of question-asking ability, we examined the order in which children demonstrated at least minimum competence on the three question-asking tasks. We defined minimum competence as (a) asking *any* categorical question on the questions for problem-solving task, (b) asking *any* questions at all on the questions asked for learning task, and (c) scoring 75% or higher on the recognizing effective questions task (6/8 correct responses, where 4/8 is chance responding). We assigned a score of 1 for passing and 0 for not passing each task, according to these criteria. Then we summed across the tasks, to determine how many children passed how many tasks: 19 (20%) children passed no tasks, 29 children (31%) passed one task, 31 children (33%) passed two tasks, and 15 children (16%) passed all three tasks. We then looked at the groups of children who passed one or two tasks, to determine which tasks were passed at higher rates. We used a series of Chi-square analyses to explore the patterns of development. When children passed only one task, it was most often the questions asked for learning (52%), and rarely the recognizing effective questions task (17%), with 31% children passing only the questions for problem-solving task (p = .03 between questions asked for learning task and recognizing effective questions task; p = .073; between questions for problem-solving task and recognizing effective questions task p = .29; between the two generation tasks p = .22). When children passed two tasks, the recognizing effective questions task was again passed least often: 5 (16%) missed the questions asked for learning task, 2 (7%) missed the questions for problem-solving task, and 24 (77%) missed the recognizing effective questions task (all comparisons with recognizing effective questions task $p < .001$). Thus, it appears that children find it more difficult to *recognize* an effective question than to *generate* one, at least in the operationalization of each type of task that we used in this study. However, our results do not make a clear distinction between the developmental paths of generating the two different types of questions investigated here (i.e., questions asked to solve a problem solving and questions asked in order to learn).

Discussion

The goal of this study was to better understand the relations among questions children ask in the pursuit of different goals, e.g. problem solving and learning, and the relation among types of question asking and curiosity. We assessed the quality of children's ability to produce questions for problem solving and for learning, as well as children's *recognition* of effective question asking using a novel task. We found that even preschoolers could generate questions both for problem solving and learning, and they could identify the effectiveness of questions (i.e., whether they were helpful or not-helpful). Performance on all question-asking tasks improved between kindergarten and first grade, and performance the question-asking tasks related as expected, with children's ability to ask questions for learning and to recognize effective questions also relating to curiosity. These results are discussed further below.

Previous studies provide a wealth of findings about question asking, including the influences on the frequency of questions asked (e.g., Tizard & Hughes, 1984), children's ability to formulate structurally appropriate questions (Van Der Meij, 1994), the developmental course of children's ability to learn from potentially effective questions (Callanan & Oakes, 1992), and children's understanding of *whom* to question and *what* to ask (e.g., Mills et al., 2011), in order for questions to be effective in gaining information. The work presented here adds to this body literature by describing and comparing the developmental course of some common, but distinct, types of question asking (e.g., for problem solving vs. learning, generating vs. recognizing), and the way in which curiosity is related to the type of question asking.

Development of the ability to generate effective questions

As expected, our three question-asking measures showed improvement with age. On questions for problem solving (the referential task), we observed developmental improvement consistent with previous studies, although performance on our task was lower than some studies. For example, past research has found that of preschool and kindergarten-age children's total questions on this type of task, 40–60% were effective categorical questions, providing new relevant information about the target (e.g., Legare et al., 2013). In the current sample, this is similar to our first-grade participants, but much higher than the preschool and kindergarten participants. This difference is likely due to variations in the protocol used from prior studies. In the current study, children were permitted to ask questions *or* guess the target until they found it, a type of less-effective hypothesis testing than using categorical questions. Prior studies only allowed a single guess of the target. In studies where participants were permitted to ask any type of questions, even older children showed a proportion of categorical questions similar to what was observed in the current study (Ruggeri & Lombrozo, 2015). Thus, these studies are complementary: although previous studies show that children are capable of asking effective categorical questions, few preschool and kindergarten children in the current study actually used these questions for problem solving, with first graders showing evidence of higher frequency of effective questioning. Legare and colleagues report that when children do ask these questions, that they are often, but not always, effective in providing relevant information and that questions asked relate to accuracy on the task (Legare et al., 2013). Although these findings present evidence of the use of comprehension monitoring skills (Whitehurst & Sonnenschein, 1985), the results reported in our study suggest that children still need practice in evaluating information so as to formulate effective questions (Jirout & Zimmerman, 2015).

The results similarly showed a developmental improvement in questions asked for learning. Although most (90%) children gave *some* verbal response relevant to the topic, only 60% of children generating one or more questions, and – as expected – older children asking more questions (e.g., Chouinard, 2007; Kemler Nelson et al., 2004). Prior observational studies of children's questioning have shown that young children ask many questions during unstructured interactions, such as when at home with a parent (Chouinard, 2007). It is likely that children's ability to ask questions to address specific knowledge goals, and asking higher-level questions, continues to develop long after they begin to ask questions (Chin & Brown, 2002; Graesser & Person, 1994; Ronfard et al., 2018). These more defined questions are important for learning, especially in educational contexts (Wisher & Graesser, 2007). Related to this, we did observe that all questions asked across age groups were relevant, and declarative statements that were not questions were still relevant (i.e., about the topic). We did not see a developmental trend in the proportion of fact to explanation questions, consistent with previous research showing similar equivalence in these question types by the preschool ages (Chouinard, 2007). Children's question asking was supported in the current study by providing both unlimited opportunity and some familiarity with the topic about which they were asked to generate questions (Scardamalia & Bereiter, 1992), and it would be interesting to test the specific effect of this support in future studies. It is also important to explore children's question asking in less structured contexts where the topic is not defined, especially when exploring relations to curiosity. Although children's questions were relevant to the given topic, prior research shows that when children seek more complex information, their questions often do not adequately request it (Kemler Nelson et al., 2004). To further explore if children are capable of judging whether their question provides desired information, a novel task was developed to specifically assess children's ability to recognize effective questions.

Development of the ability to recognize effective questions

Prior studies show evidence of children's ability to assess the effectiveness of questions as early as first grade, such as first to second grade children's use of effective questions on a 20-questions style "Guess Who" game (Nelson et al., 2014). Ruggeri and Lombrozo (2015) show that children as young as second grade are sensitive to the probabilistic information about question effectiveness, using likelihood of different answers being correct to decide on the questions asked. The current study showed that even younger children can correctly categorize questions as helpful or not helpful on a simpler task, though there were again developmental effects. The finding that children were biased toward identifying *any* question as helpful is consistent with prior studies of slightly older children on more complicated tasks, with adults (Samuels & McDonald, 2002), and with earlier findings that preschool children are better able to judge conclusive evidence as conclusive, than to judge inconclusive evidence as inconclusive (Fay & Klahr, 1996).

Developmental trajectories

We explored performance trajectories by comparing patterns of success across the tasks. Children succeeded on both of the question *generation* tasks before they succeeded on the task that required them to *recognize* effective questions. It is possible that our generation tasks relied more heavily on the initiation and formulation stages of Ronfard's question-asking model, and that our recognizing effectiveness task was similar to both the formulation and response evaluation stage, as both require the child to compare the information that the answer to a question might provide to the knowledge embedded in the problem space (Ronfard et al., 2018). Our results were not able to disambiguate the developmental order for questions asked for problem solving vs. questions asked learning.

Our exploratory results suggest that children are able to *generate* questions before they are able to *recognize* their effectiveness. Initially, this seems counterintuitive; children must evaluate what is unknown in all tasks, but the generation tasks have the additional demand to construct and verbalize a question – and children clearly verbalize questions early (Chouinard, 2007). However, this does not consider question effectiveness – and evaluating effectiveness also has additional demands, including analysis of prior knowledge and higher-level evaluation of information. Indeed, prior research finds that children are able to identify informative questions to ask before generating informative questions (Ruggeri, Sim, & Xu, 2017). These inconsistent results likely reflect differences in the tasks. We observed a bias in categorizing questions as helpful more frequently than as not helpful (i.e., more than half of the questions were categorized as helpful), however in prior research children compared the helpfulness of questions relative to each other, making it a somewhat different task (Ruggeri et al., 2017). The task in this study also relied on children's prior knowledge about animals to evaluate the information (e.g., deciding whether or not information about what an animal eats is helpful requires you to consider whether animals in the set being considered differ in what they eat), and the unnecessary information from the not-helpful items may have distracted from thinking about potential helpful information. Similarly, our questions for learning task were less restrictive in what an 'effective' question was than the informative questions assessed in prior studies. Research is needed to explore whether this evaluation of effectiveness is more complex than generating questions, because these exploratory analyses are limited by the coding used. Additionally, slight manipulations of the measures in this paper could allow for more carefully study the specific processes involved to further explore developmental patterns.

Relations among, and development across, tasks

Our cognitive task analyses (CTAs) for the three question-asking tasks revealed a complex set of (possibly common) sub-processes underlying these aspects of questioning. Consequently, we looked for related associations in children's performance on the three tasks. Children's performance on the questions for problem-solving task was correlated with both the questions for learning task and the recognizing effective questions task. However, there was no significant correlation between those two tasks. These empirical correlations are consistent with the fact that, in several cases, the CTA's for the different tasks contain some common components. In both the questions for problem solving and questions asked for learning tasks, there was a reliance on Ronfard's "formulation" stage, in which children must generate a question that addresses specific desired information (Ronfard et al., 2018). Interestingly, scores on the questions for problem-solving task correlated higher with the frequency of explanatory questions than with fact questions (which are more similar in type to those asked on the problem-solving task), suggesting that children who are better at asking effective questions for problem solving might ask more sophisticated questions in general. In recognizing effective questions and asking questions for problem solving, children were given similar goals: identifying a target, either from an array in questions asked for problem solving, or a hidden animal from all possible animals in the recognizing effective questions task. However, recognizing effective questions may have relied more heavily on experience and prior knowledge about both learning from questions and about animals, rather than solely relying on visual cues provided in the questions asked for problem solving. The former is more similar to how questions are used in real-world problem solving, suggesting that use of 20-questions style tasks in research is related to the processes needed for more naturalistic question asking for problem solving. Questions asked for learning differed from the other tasks in that the children were given the topic to ask about, but without having a well-defined problem space and goal (i.e., solving a problem).

Children who were more curious – i.e., those who preferred to explore when there was more uncertainty on the exploration game, were better able to categorize questions as helpful and not helpful. However, although a median split of curiosity scores showed high-curious children asking more questions, the overall correlation was not significant and we are unable to draw strong conclusions about this result without further testing. The process of thinking of questions about a topic to ask is relevant for the more metacognitive process related to asking questions – understanding what one does and does not know about a topic (Ciardiello, 1998). Similarly, evaluating question effectiveness also relies on metacognitive processes of coordinating new information, what is already known, and prior knowledge, to determine whether the new information is useful, and the curiosity task more generally relies on children's reasoning about uncertainty related to the different levels of information presented. On the other hand, because curiosity in this study is defined as preference for exploring greater levels of uncertainty, it can be assumed that those children who show this preference are more likely to have the need for asking more questions, and so have more practice at this, as well as more experience with feedback from their questions to help learn to recognize question effectiveness. On the questions for problem-solving task, there is no clear incentive for question-asking strategies to differ based on curiosity: all children were resolving the same amount of uncertainty, perhaps explaining the lack of relation between curiosity and questions asked for problem solving. Consistent with Luce and Hsi (2015) work, it is likely that there are different types of questions that relate to different goals and motivations, with some being driven more by curiosity than others. The current study shows that although these differences exist, the different related processes still show overlap as evidenced by relations between task performance. Further work using processes identified in the CTAs could support the identification of processes that children find most difficult so as to inform targeted interventions, and could also include additional measures of constructs likely to relate to performance across the tasks, such as metacognition.

Limitations and future directions

The data for this study only had grade-level information about age groups, rather than individual ages, limiting our ability to control for age in our analyses. This is an important consideration for future research to address in exploring developmental questions. The study was also limited in the difference in sample size across grades, and especially the small sample of preschoolers. Future work should attempt to replicate the findings while further studying the development of question asking. The alignment of different types of question-asking tasks with a proposed model of question asking (Ronfard et al., 2018) and cognitive task analyses demonstrates the potential benefits of including multiple measures when studying question asking to gain a more holistic picture of children's overall question-asking ability. The tasks used here do not provide knowledge about the development of the more specific question-asking processes, but future research could modify them to explore this, as well as assessing more general questions about the reliability and validity of the tasks.

The two novel features of this study are (a) the inclusion of three distinct measures of question answering, and (b) the inclusion of an operational measure of curiosity and an assessment of curiosity as a fundamental motivator for asking questions. Our aims were to investigate the development of different types and processes of question asking from preschool to first grade, and to assess the relations across question-asking types and between question asking and curiosity. Previous investigations of children's question-asking abilities demonstrate that even preschool children have the capacity to ask "good" questions, but this study revealed that they may not spontaneously do so in structured problem-solving or learning tasks, and that the frequency and effectiveness of their question-asking improves significantly between kindergarten and first grade, with little difference from preschool to kindergarten. In addition to revealing some interesting developmental effects, our results illuminate some of the interrelationships among different types of question-asking processes and between question asking and curiosity.

One way to learn is to ask questions, and questions are a potentially valuable tool to enhance student learning in classrooms (Ciardiello, 1998; NRC, 2012). Effective questions will more successfully yield desired information, enhance understanding, and help in problem solving. Future work should further explore: (a) the relationship between different types of question asking and learning, (b) the mechanisms by which effective question-asking abilities develop, and (c) how that development can be supported and fostered, especially during the preschool years, in which our investigation revealed very weak question-asking performance.

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