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Teacher Questioning Practices in Early Childhood Science Activities

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Abstract
This study explores teachers' use of questioning during collaborative science exploratory activities. We classified a total of 755 questions across 14 preschool science lessons implemented by four teachers by type (open- or closed-ended) and content (science- or non-science-related) while also recording the intended recipient. Results revealed that, overall, teachers primarily asked closed-ended questions to children during preschool science activities. While closed-ended questions outnumbered open-ended, science-related questions were more likely to be open-ended questions. We noticed this trend whether the teacher directed the question to a group of children or an individual child. Gender of the child recipient was also explored with no significant differences found. Results indicate that collaborative science exploratory activities may be an ideal context for increasing teachers' use of open-ended questions. Background and training of teachers may also play a role in the use of open-ended questions in a science activity context.

Keywords: early childhood, science, teaching strategy, questioning

Introduction

Young children are capable of understanding science content and processes (National Research Council [NRC] 2012), and adults can encourage and facilitate children's science learning (National Association for the Education of Young Children [NAEYC] 2013). Teachers can guide this learning in several ways, including creating developmentally appropriate activities for exploration, providing explanations, and asking questions (NAEYC

2013). Questions are a common classroom occurrence, and nearly all teachers use the strategy of questioning to stimulate and deepen children's thinking (Kostelnik et al. 2015). While an increasing amount of research has emerged on the importance of science in early childhood education, little is known about how questioning is used in the context of collaborative science exploratory activities in preschools. Young children and their teachers are actively engaged in elements of the scientific process every day, and researchers are working to learn more about the intricacies of these processes. In this study, we examined the instructional strategy of asking questions in the context of preschool science activities. More specifically, we explored teachers' use of questioning during preschool science activities by examining three main factors: the intended recipient of the question (i.e., to whom the question was directed), the content of the question (i.e., science-related vs. non-science-related), and the cognitive level of the question (i.e., open-ended vs. closed-ended).

Supporting Scientific Exploration in Preschool

Research supports starting science experiences early in life as a way to develop scientific thinking, create a positive attitude toward science, and expose young children to science concepts early on (Eshach and Fried 2005; Morgan et al. 2016). Elements of the scientific process are naturally connected to children's interest in and curiosity of the world around them. It is within this context that a shift in how we consider science teaching and learning in young children is situated. Science was once thought of as passive learning of facts related to scientific concepts (Yoon and Onchwari 2006). The continued evolution of teaching science into a more active exploration or "doing science" is especially beneficial for early childhood educators who have reservations about their own science content knowledge and their ability to facilitate children's science learning (Pendergast et al. 2017). In fact, teachers describe their lack of confidence and content knowledge as a barrier to teaching science (Gerde et al. 2018; Kallery and Psillos 2002).

Shifting away from providing prepared, passive learning through teacher-centered experiments to providing children a more active role in science exploration is a much needed transition in early childhood science teaching. This shift enables teachers to explore a developmentally appropriate way to incorporate science into the classroom and also tends to relieve the burden of the teacher to know everything. It modifies the role of the teacher from provider of information to more of a guide intentionally aiding children's exploration of scientific concepts through hands-on play, leading to a co-construction of knowledge. For the purpose of this paper, these experiences will be referred to as *collaborative science exploratory activities*. The construction of knowledge between teacher and child suggests learning through collaborative social interactions and is, therefore, the rationale for applying Vygotsky's theory of social-cultural constructivism (Vygotsky 1962) as the framework for this research. Vygotsky proposes that children's knowledge is constructed or shaped through interactions with those around them and is not generated from within. The collaboration among individuals (e.g., children, their peers, and teachers) during social interactions guide cognitive development through the use of language and culture. This perspective is applicable because the role of the teacher in this context could be considered that of a more knowledgeable other serving as a guide for expanding science knowledge. The interactions include scientific terms and language which are culturally defined and applied to the exploration at hand. The lens of socially mediated learning introduced by Vygotsky is well-suited for examining how teachers use language, through the specific strategy of asking questions, to guide and co-construct children's scientific understandings. Therefore, it is helpful to examine how teachers enact the common strategy of questioning during collaborative science exploratory activities intended to guide children in learning scientific concepts and processes.

Questioning Practices in Early Childhood Science

Children's learning is influenced by the way teachers ask questions (Yoon and Onchwari 2006), and the type of question asked can dictate the quality of the child's response (Kostelnik et al. 2015). Intentionally thought-out questions can challenge children's thinking and guide children to consider concepts. Minimally challenging questions are often referred to as low-level questions, whereas high-level questions require deep thinking and, thus, are considered more challenging. Some suggest that both lower- and higher-level questions are important in the classroom because higher-level questions require basic information on which to support deep thinking, and lower-level questions can provide the foundational knowledge for deep thinking (Martin 2003). The level of difficulty of teacher's questions are often identified through differentiating the type of question as either open or closed. Open-ended questions are more challenging or high-level because they, compared with closed-ended questions, prompt deeper thinking and require the recipient to move beyond a predetermined response.

Existing empirical research regarding early childhood science and questioning practices is informative but becoming outdated. In research conducted over a decade ago, Kallery and Psillos (2002) investigated science exploration and teachers use of open-ended questions. Results indicated that teachers were asking a continuous stream of questions and that they answered nearly one third of the questions themselves (Kallery and Psillos 2002). This research indicates that, although questions are being posed to young children during collaborative exploratory science activities, the quality of such questions and the value of their rapid presentation is uncertain. Furthermore, researchers found that teachers' use of science-related questions during free-play time differed significantly across classroom areas. More specifically, science-related questions were posed by teachers primarily in blocks and dramatic play areas and not in designated science areas (Tu and Hsiao 2008). Furthermore, none of the activities offered in the classroom were considered *both* exploratory and science-related (Tu and Hsiao 2008). While this research provides context to how science-related questions are used in classroom areas, it also denotes a gap in the literature in regards to examining the use of questions during collaborative science exploratory activities.

Finally, it is valuable to examine *who* teachers are targeting as intended recipients of their questions. One study that analyzed the conversations between children and their parents during a museum visit showed that parents were three times more likely to provide a scientific explanation at an exhibit to their sons than their daughters, regardless of equal amounts of conversation occurring with each gender (Crowley et al. 2001). While this research was aimed at investigating the family setting, it is conceivable that early childhood teachers may present a similar gender bias in their questioning strategy. However, other research contradicts the notion of gender bias, including a study of interaction patterns in an elementary mathematics class that found no gender differences in the number of higher-level questions asked of boys as compared to girls (Wimer et al. 2001). Notably, both studies are nearly two decades old and occurred outside of an early childhood setting, and therefore, additional and more recent research is warranted to understand to *whom* questions are intended for during preschool collaborative science exploratory activities.

In summary, as collaborative science exploratory activities are encouraged and become more prevalent in early childhood classrooms, it is important to examine the role of the teacher as a facilitator of children's science learning. Specifically, how the teacher's questioning practices have adjusted to the shift from formal teacher-centered science demonstrations and experiments to collaborative science exploratory activities.

Aim of the Study

Research on questioning practices during collaborative science exploratory activities is scarce and outdated. Little is known about how the common strategy of asking questions is used by early childhood teachers to probe the thinking of young children during such science activities. This led to our research question, "*What are the questioning practices of early childhood teachers during collaborative science exploratory activities?*" In this study, we explored the instructional strategy of asking questions by focusing on *to whom* the teacher asks questions, *what* the teacher is asking about, and *how* the teacher asks. Additionally, we sought to investigate possible associations between child gender and type of question posed and child gender and question content. We intended to further explore the data for unique patterns of questioning by analyzing the content and type of question asked by teachers. Gaining detailed insight into these elements of questioning is important for informing teacher education programs, design of early childhood science curriculum, and professional development to support children's science learning.

Method

Participants and Study Context

This study was conducted during the implementation of a larger preschool science professional development (PD). The PD program was designed to improve preschool science instruction through observation of children's science interests, teachers' reflection on their practices, and open-ended physical science materials. The project was reviewed and approved by the Institutional Review Board.

Teachers from two Head Start programs and one community child care program were invited to participate through flyers and informational letters. From these three programs, four teachers from three classrooms volunteered to participate in the study and were compensated for their time with classroom materials and books valued at approximately $500. Descriptive demographic data are summarized for teachers in Table 1. Teachers 1 and 2 worked together in the same classroom, and Teachers 3 and Teacher 4 were employed in different programs. All four participating teachers had a minimum of an associate's degree but in various fields of education and reported that they had been "fairly prepared" to teach science to three- to five-year-old children. Three of the teachers held the role of lead teacher, and one was an assistant teacher. We recruited children in each participating teacher's classrooms by sending home flyers, letters, and consent forms. However, not every child's family provided consent for participation. Our efforts resulted in a total sample of thirty-eight children, 37% female and 63% male. The ethnicity of children included 63% Hispanic/Latino, 26% Black/African American, 8% White/Non-Hispanic, and 1% Other.

Table 1. Teacher and setting information

	Program	Educational background	Years of teaching preschool	Type of preschool	Role
Teacher 1	Head start program location A	MEd in special education	5	Public	Assistant
Teacher 2	Head start program location A	MEd in physical education	17	Public	Lead
Teacher 3	Head start program location B	BA in early childhood education	11	Public	Lead
Teacher 4	Community child care program	Associate degree in child development	Not reported	Private	Lead

Note: MEd = master of education, BA = bachelor of arts

Data Collection

As part of the larger science PD project, teachers participated in a cyclical process of observation, activity implementation, reflection, and planning (Gandini and Goldhaber 2001). Researchers video-recorded classroom interactions during science activities prepared by the teacher. Teachers designed activities and environments based on children's interests and science objectives and were recommended to use open-ended materials. Teachers implemented the activities in a variety of formats including small group (two to six children), slightly larger group (seven to nine children), and free play times depending on what teachers determined would work best in their setting. Two of the teachers contributed four video clips each, and two teachers contributed only three video clips due to scheduling issues. In total, 14 videos of collaborative science exploratory activities were collected and analyzed for the study.

Data Analysis

The lead author viewed each video in its entirety prior to transcribing and noted the format, duration, materials, and topic of the lessons. The format varied with some activities occurring in small group (two to six children), slightly larger group (seven to nine children), or free play times in which children moved freely in and out of areas joining their peers or working alone throughout designated areas of the classroom. Videos ranged in length from 11 min 30 s to 28 min 40 s, and all the science activities included open-ended materials covering a variety of physical science topics, such as speed, construction of structures, angle of inclination, and friction.

To answer the research question *What are the questioning practices of early childhood teachers during collaborative science exploratory activities?* the lead and the second authors transcribed teacher and child dialogue captured in the 14 videos. In addition to questions, statements were also transcribed verbatim as they provide a context for understanding the questions. The context surrounding teacher questions alluded to the nature of the topic being discussed and helped determine the content of the question. All child responses to the teacher were transcribed as well. In contrast, utterances by children outside of teacher interactions were not transcribed. For example, in a science activity taking place during free play time, several verbal interactions occurred between teacher and child, child and child, and even teacher and teacher. However, given that the focus of the current study was to examine teacher questioning of children, conversations among children and those among teachers were not transcribed. The analysis of the transcripts centered on three objectives: identifying the recipient, content, and level of difficulty of the teacher's questions.

Intended recipient

During transcription, the intended recipient of each question and statement was noted using a unique identification number. At times, the teacher spoke to multiple children at once. For example, at the start of an activity, the teacher might ask a group of children to recall information or ideas from a previous lesson. In that case, we coded any question aimed at more than one child as being intended for a group. Group sizes ranged from 2 to 9 children. At times, the intended recipient was not visible in the video because of children moving in and out of centers around the room. In such circumstances, the intended recipient was coded as "unknown" and not included in analysis.

Question content

We defined the content of questions as science by using process standards and concept objectives for physical science combined from the Nebraska Early Learning Guidelines (Nebraska Department of Education 2018), a published review of literature (Hong, Torquati and Molfese 2013), Teaching Strategies® for Early Childhood (Heroman et al. 2010), and the High Scope Educational Research Foundation (2003). A description of physical science concepts and processes is provided in Table 2. We used the description identified in Table 2 as a guide for coding the teacher's questions. Each question was coded as a "1" if it contained science content or process information and a "0" if it focused on any other non-science-related topic (e.g., classroom and behavior management).

Table 2. Physical science process and content

Physical Science	Examples
Processes	
Make observations, collect information, describe objects and processes[a]	*The teacher presents the child with a set of ramps and a basket of small items varying in shape and size. The child selects items from the basket and puts them on the ramp, closely observing them. He notices that smooth, round items roll down the best and items with corners and sides slide off the ramp or don't move at all. When another child joins the play, he explains, "Don't use the sharp ones, they don't work."*
Make comparisons between objects that have been observed[a]	*Child observes items as she places them in a tub of water. She notices if the item sinks to the bottom or floats on top. She takes the item out and puts it in a pile depending on its ability to sink or float. At the end she points to the "Sink" Pile and concludes, "These all dropped to the bottom because they are heavy."* *A child places lunch leftover on a plate to see what will happen to the food over time. The teacher helps the child safely cover the plate and document it using a camera and a journal. Each day the child returns to the plate, uncovers it to take a picture, and draws a picture of what has happened. Over time he refers back to his original drawings and photographs to compare the food to its current molding state. The child compares the color, smell, and appearance of the food over time.*
Look for answers to questions through active investigation[a]	*One morning a girl and her friend notice their shadows outside on the playground. As they enter the playhouse they no longer see their shadows. The girls go in and out of the play house watching their shadows disappear in the house and reappear in the sunlight. They run to other areas of the playground to investigate, and they make guesses about where the shadows will be visible and where they will disappear.*
Uses scientific inquiry skills[c]	*Children ask what would happen if some materials were added during a sink and float activity with a toy boat. The children begin to make predictions and experiment by adding objects to the toy boat deck to actively investigate and answer their question.*
Use senses, materials, tools, technology, events in nature, and environment to investigate and expand knowledge[a]	*A group of children and their teacher go on a scavenger hunt around the school building. They each carry a magnet wand. They explore their environment with the wands to identify items in their school building that are magnetic. The children look at, feel the pull, and hear the click of the magnetic items coming together.*
Uses tools and other technology to perform tasks[c]	*Children use sieves, buckets, and scoops in the outdoor play space. After they scoop up sand, rocks, and other natural materials, they pour it through the sieve into the bucket. Next, they use magnifying glasses to examine the items that were too large to pass through the sieve.*

Table 2. *Continued*

Physical Science	Examples
Content/concepts	
Child describes or represents a series of events in the correct sequence[a]	*Child examines photos taken by the teacher of a snowman the class built at various stages throughout the winter and into the spring. The child puts the photos in sequential form from frozen to melted.*
Child demonstrates understanding of natural processes and simple cause and effect[a]	*During a demonstration of a volcano, each student gets to pour in vinegar, a liquid that causes the volcano to erupt, and is asked why.*
Child shows interest in measurement of time, length, distance, and weight[a]	*Child compares own handprint to those of peers, teachers, and parents. Child notices the differences in size and compares them.* *Children predict how much two or three items weigh. Then together the items are weighed and charted. Children notice how close their guess was with the actual weight, using words like more, less, and same.*
Properties and characteristics of liquids, solids, and gas[b]	*The teacher fills a small sensory table with ice cubes. Children explore the ice cubes and visit the table throughout the day to view the change of the ice cubes over time. Children notice that at first they were hard squares but at the end of the day they changed into water they can pour into different-size containers.*
Explores characteristics of matter[b] Demonstrates knowledge of the physical properties of objects and materials[c] Identifies materials and properties[d]	*A child in the sandbox is scooping sand into a variety of buckets and bowls. The child listens to the sand hitting the inside of the containers and tells his teacher that the sounds are different because containers can be made from different materials like metal, wood, and plastic.*
Explores force, motion, and energy[b]	*Children working in the garden find their pumpkin has fallen off the vine. They want to bring it into the classroom to show families. After recognizing it's too large to carry, the children explore ways to move the pumpkin by pushing on it, rolling it across the yard, and trying to pull it in a wagon. Children show understanding that pushes and pulls can be different strengths and direction.* *While building a ramp, a four-year-old boy builds a curved path traveling downward and uses straight blocks along the edges to try to keep the marble from rolling off the curve as it picks up speed.*

[a]Nebraska Department of Education (2018)
[b]Hong et al. (2013)
[c]Teaching Strategies for Early Childhood (2010)
[d]High/Scope Educational Research Foundation (2003)

Level of difficulty

For the purposes of this research, open-ended questions were defined as those questions that did not have an established or known answer and which did not limit the child's response (de Rivera et al. 2005; Hargreaves 1984). An example of an open-ended question was found in a video of children using ramps covered with varying textures to explore speed and friction when the teacher asked, "Why did it go slow?" Children's responses are not limited by a set of options and require deeper thought about why a phenomenon is occurring. Conversely, a question that limited a child's response with a forced option, such as yes or no, was defined as closed-ended (de Rivera et al. 2005; Hargreaves 1984). For example, in a video of a child using a transparent, color-tinted paddle to explore color mixing, the teacher asked, "What color is that?" Children are limited in their response by the set of primary colors seen in the color-tinted paddles and further thought or explanation are not required to respond outside of identification of the color. We used these descriptions as a guide for coding questions as either open-ended (1) or closed-ended (0).

Interrater reliability

To ensure interrater reliability, four transcripts (i.e., one from each teacher) were selected for comparison. The first and the second authors coded the transcripts independently of each other and met to compare coding and check interrater reliability. Three of the transcripts had greater than 87% consensus; however, one transcript had less than 80% reliability. Although we agreed on the level of difficulty of teachers' questions (i.e., open-ended vs. closed-ended questions), further investigation revealed that most of the discrepancies were about the content of the questions (i.e., science-related vs. non-science-related questions). The main challenge was in determining the content for questions that were not explicitly science-related when observed out of context. These questions initially appeared to be *not* science-related but, within the context of the lesson, they were, in fact, prompting further thinking about science processes or content. For example, when working with ramps, cars, and balls, sometimes teachers would ask "Are you ready?" in the context of experiments. Standing alone, this question did not sound like a scientific question. However, within a larger conversation of the importance of releasing the ball at the same time in order to see which reaches the bottom first, teachers used those questions to facilitate children's experiment about physical science concepts, such as speed and weight. Thus, we agreed that the questions not directly related to science but within a valid science context were regarded as science-related questions. Guidelines for coding the content of questions were created to help us achieve and maintain a minimum of 80% reliability. These guidelines for identifying science content are outlined in Table 3. Based on those guidelines, the researchers achieved over 80% reliability on over 25% of the transcripts (i.e., 4 out of 14 transcripts).

Table 3. Guidelines for identifying content as science-related or non-science-related

Example question(s)	Content code
What are you building/going to build/did you build?	Science-related—prompting explanation
Do you guys want to play with balls? Put it down? Try it again? Put it together?	Science-related—contributing to an established science-related scenario
Do you see these? See how it fits like a puzzle?	Science-related—drawing attention to scientific details
Did you hear my question?	Non-science-related—group management
How we doing friends?	Non-science-related—used to enter scenarios
Okay, ready? Are you ready? When I say go, ready? Ready to see what happens?	Dependent on overall context
What did you do?	Dependent on overall context

Results

The total number of questions (*N* = 755) was descriptively summarized for each of the three main variables (recipient, content, and question type). Analysis of the content of teachers' questions revealed that more than three-fourths (76%) of questions asked were related to science while the remaining 24% were not science-related content. Overall, closed-ended questions were asked much more frequently than open-ended questions: only 22% (*n* = 162) of all questions asked were identified as open-ended and 78% (*n* = 593) were identified as closed-ended. While 70% of the questions were aimed at male children and 30% intended for female recipients, this finding reflects the demographics of the child sample. A further explanation is provided below along with description and analysis for each main variable.

Who Teachers Ask

Descriptive statistics were used to identify the frequency of questions that teachers posed to individual children as compared to groups of children. Results indicated that, of the 685 questions with an identifiable recipient, just over one third (i.e., 235 questions; 34%) of teachers' questions were posed to groups (2–9 children), while the remaining 66% were intended for individual children. Tables 4 and 5 shows an analysis of questions posed to groups by number of children in each group, with most group questions (80% of 235 questions posed to groups) posed to 2–6 children and the remaining group questions (20% of 235 questions posed to groups) posed to larger groups of 7–9 children.

Table 4. Association between type of question and content of question

	Content of question		
Type of question	Science-related	Other	Total
Open-ended	156	6	162
Closed-ended	420	173	593
Total	576	179	755

Table 5. Questions asked of groups of children by number of children in a group

	Questions	
Children in group	n	%
2	51	21.7
3	39	16.6
4	18	7.7
5	49	20.9
6	32	13.6
7	0	0
8	39	16.6
9	7	3.0

We further analyzed the questions posed to individuals, specifically focusing on the gender of question recipients, to examine the potential association between the gender of a child recipient and the type of question (open- vs. closed-ended) that teachers pose. However, this analysis revealed no significant differences ($\chi^2(1) = 0.01$, $p = 0.91$). In short, teachers in this study asked boys and girls equal numbers of open- and closed-ended questions.

In addition, we conducted a similar analysis examining the potential association between the gender of a child recipient and the content of the questions that teachers posed. This analysis also revealed no significant differences ($\chi^2(1) = 0.46$, $p = 0.50$), indicating that teachers asked boys and girls a proportionate number of science-related questions.

What Teachers Ask About

The total science-related questions far outnumbered questions on other content. Table 4 shows the contingency table for the type of question and the content of question. Analysis revealed that there was a statistically significant association between the two variables ($\chi^2(1) = 45.64$, $p < 0.001$). In other words, science-related questions posed by teachers were more likely to be open-ended than questions about other content.

We also explored individual teachers' questioning patterns to find out if the content of questions asked during science activities varied by teacher. An overall effect was found that indicated a significant difference across teachers ($\chi^2(3) = 40.95$, $p < 0.001$). A further follow-up analysis using pairwise comparisons indicated that two participating teachers, Teacher 1 and Teacher 2, asked significantly more questions about "other" content than the other two teachers. A further examination of this finding is reviewed in the discussion section.

How Teachers Ask

Teachers used more closed-ended questions than open-ended questions, with only 21% of the total questions asked identified as open-ended. This main effect was true for all teachers; however, a further analysis revealed that one teacher used open-ended questions significantly less than the other three teachers. Teacher 2 asked significantly less open-ended questions than the other three teachers ($\chi^2(3) = 25.75$, $p < 0.001$). An exploration of demographic factors to help explain this finding is provided in the discussion section.

Discussions and Implications

In this study, we examined early childhood teachers' use of questions during collaborative science exploratory activities in three ways: *to whom* teachers ask, *how* they ask, and *what* they ask about. This study extends the research on one aspect of teacher-child interactions during science activities by providing information about how teachers adjust to the role of a guide that encourages active child learning and science investigation during collaborative science exploratory activities.

The majority of questions (66%) asked during collaborative science exploratory activities were addressed to individual children. This result shows that teachers tend to engage in verbal interactions about science with individual children and might suggest that the teacher was playing a role as a guide for individual children even while exploring science collectively. Given the exploratory nature of the presented science lessons, these verbal interactions were tailored to a specific science concept and the individual child's level of understanding and topic of interest, in contrast to questioning of groups that limits opportunities for individualization. Revisiting the application of Vygotsky's idea of constructivism to this work prompts us to also consider the collaborative nature of science exploratory activities. Vygotsky posited that a more knowledgeable other could help facilitate or guide children's learning, a role often attributed to the teacher. In this study, teachers' questioning of an individual child was more common than questioning directed at groups of 2–9 children. This finding may suggest that teachers were attentive to individual children's science learning within collaborative science exploratory activities. However, it is unknown to whom teachers' questions would likely be addressed when these science activities occur in a large (whole) group context.

Scientific knowledge can be considered a collective pursuit as individuals participate and do science in collaboration with one another (Siry et al. 2012). In the context of the collaborative nature of these activities, it is also important to consider other interactions outside of the teacher that contribute to learning and understanding: most notably, the influence that peers might have on one another during science activities. For example, researchers who investigated how 5- and 6-year-old children participating in small scientific inquiry groups make meaning of water through their actions and discourse among peers found that children participating in a goal-oriented science activity discussed science, used familiar ways of making sense of information, and showed awareness of doing science to collaborate and complete the science-related activity (Siry et al. 2012). This suggests that co-construction of science occurs among peers through their interactions with one another. Using questions could be one way for teachers to illicit discussion and collaboration among children. However, future research should also consider how teachers can build a climate of collaboration during science exploratory activities while also helping to advance individual children's interests.

Another assuring finding is the lack of significant differences between genders in the type and the content of questions asked. Teachers' actions and words can convey gender bias and even influence the type of activities in which young children participate and interests that they develop, which can impact later career choices (Bian et al. 2017). Results from the current study indicated that questioning practices did not differ due to gender of the child recipient. While it should be noted that the sample size of teachers was small, it is promising that girls and boys were asked similar numbers of science-related and open-ended questions. It is important to consider how to maintain this trend into elementary school where girls show less interest in science than boys, with girls demonstrating a waning interest with age so that by ages 10–14 years, a marked difference in science attitude by gender is evident (Catsambis 1995; Kotte 1992). Another set of evidence notes that a gender gap in science achievement begins as early as elementary school and persists over time (Morgan et al. 2016). Findings of this nature have resulted in a call for intervention at an early phase of development. Maintaining interest in science is important for all children but especially for preschool aged girls whose level of science interest predicts a significantly higher understanding of their own scientific abilities, values, and attributes at eight years old (Leibham et al. 2013). The role of the teacher as a facilitator during collaborative science exploratory activities should continue to be investigated because of the critical need to maintain equal science experiences for both genders in their future schooling.

Overall, teachers asked more science-related questions than other-content-related questions. This is not surprising, given that the context of the current study was part of a larger PD project focused on collaborative science exploratory activities. However, an interesting finding was that, while the closed-ended questions outnumbered open-ended questions, science-related questions were more likely to be open-ended than non-science-related questions. This finding suggests that collaborative science exploratory activities may be an optimal context that provides greater affordances for teachers to ask higher-level questions that stimulate children's thinking. From this finding, we can imply that teachers of all levels working to improve their questioning techniques may find multiple opportunities within the context of a collaborative science exploratory activity. Furthermore, it supports findings from Tu and Hsaio (2008) that teachers asked more science-related questions in certain areas of the classroom, such as blocks, than they did in traditional science centers. In this study, teachers' science lessons were specifically based on physical science objectives and often took place in the blocks area with traditional, open-ended block-center materials. We suggest a focus on the open-ended, exploratory, and collaborative nature of science activities to promote science-related questions rather than concentrating on the physical location of the activity.

Further exploratory analyses revealed a significant difference in the use of questioning among teachers. First, Teacher 1 and Teacher 2 were found to ask significantly more non-science-related questions than the other two participants. Notably, these two teachers were from the same preschool classroom and the culture of the classroom may have led to more non-science-related questions. More specifically, the teachers were at times preoccupied with managing children's behaviors, which may have resulted in more questions being asked that were focused on other topics and not science-related. Second, Teacher 2 tended to use more closed-ended questions and asked fewer science-related questions to children in science activities than the other three teachers. This teacher had a master's degree in physical education and an extensive amount of teaching experience in preschools. However, she reported that she had not received science-related training for early childhood. Literature shows that teachers' field of education as well as the amount of additional training in certain content areas could influence their teaching practice and child outcomes (Burchinal et al. 2008; Egert et al. 2018; Honing and Hirallal 1998; Howe et al. 2011). The lack of early childhood–related training reported by the one teacher may have influenced her questioning practices in the classroom.

Limitations and Future Directions

Although the individual questions asked was the main level of analysis ($N = 755$), a small sample size of only four teachers limited the scope of our analyses. More specifically, teacher characteristics, such as education level, field of education, and their prior experiences, could not be considered in statistically analyzing their questioning practices. In addition, the types of preschools that participated varied with three classrooms being part of a public preschool and one part of a private preschool program. The curriculum of these programs varies and may have had an influence on how teachers interacted with children. Teachers who are used to a scripted curriculum may not find it as easy to generate their own open-ended questions as their colleagues who implement an emergent curriculum. In addition, social desirability may have played a part in teacher's implementation of lessons. While researchers were discreet while videotaping, the irregularity of the visits drew the attention of children and teachers, who may have enhanced their practice due to the presence of the researcher. In addition, we lack a complete view of two of the teachers' practice due to the absence of their follow-up videos.

Future research should consider other aspects of questioning, such as the amount of wait time that teachers present to children after asking questions. Children whose teachers pause for three or more seconds after asking a question and again after children share a response benefit from a higher level of discourse and cognitive learning (Rowe 1986; Tobin 1987). In addition, children's response is an aspect of questioning that deserves attention. A child's verbal response could lead to reorganizing their thoughts and deeper learning (Fuson et al. 2005). It also could provide an opportunity to analyze dialogue for multiple exchanges between a teacher and a child, which can provide further information on how the teacher guides the child through learning. Finally, although the cognitive demand that a question poses is often categorized as high or low for open- and closed-ended questions, respectively, questions can also be classified by their purpose, such as gathering information, probing thinking, and encouraging reflection and justification (Huinker and Bill 2017). Coding questions by their purpose would provide further knowledge on how teachers use questions as an instructional strategy during science activities.

In conclusion, the role of the teacher as a facilitator or guide during exploratory science activities has recently been encouraged in early childhood (Hamlin and Wisneski 2012). As teachers adjust to this role of teaching science, a domain in which they often lack confidence, it is important to assess and examine their interactions and use of teaching strategies to prompt learning. In this study, teachers posed more science-related questions than non-science-related questions but primarily in the form of closed-ended questions. However, when teachers did pose an open-ended question, it was more likely to be science-related. Teacher training and classroom culture may also play a role in the use of open-ended questions during science activities which warrants further investigation.

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