Questions in a Life-Sized Board Game: Comparing Caregivers' and Children's Question-Asking Across STEM Museum Exhibits

Lay Abstract

We investigated whether children's and caregivers' questions about math, spatial, and scientific topics could be increased in a museum exhibit specifically designed to promote this type of questioning. We found that both caregivers and children asked more of these questions when playing in Parkopolis, a life-sized mathematical- and spatial-themed board game than in a control exhibit. Our findings have implications for how other informal learning spaces can be designed to increase question-asking and conversation.

Abstract

Parkopolis, the life-sized board game, was designed to promote conversation and STEM learning. We asked whether this exhibit also prompted questioning. Caregivers' and children's STEM-related question-asking was compared between Parkopolis (i.e., experimental group) and a STEM-themed control exhibit. Groups (N = 197) of children and caregivers visiting two exhibits in a museum were observed. Observations revealed that caregivers and children asked more mathematical questions in Parkopolis than in the control. Caregivers also asked more spatial questions in Parkopolis. Additionally, when all STEM-related question topics (i.e., mathematical, spatial, and scientific thinking) were combined, children asked more STEM-related questions in Parkopolis than in the control. Lastly, children responded to a higher proportion of caregivers' questions in Parkopolis than in the control. Factors that promoted this question-asking in Parkopolis, such as signage and the interactive nature of the exhibit, can inform the design of other informal learning spaces to promote question-asking.

Keywords: questions, STEM, informal learning, playful learning, museums, signage

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Asking and answering questions fuels children's learning (Chouinard et al., 2007; Yu et al., 2019). Caregivers ask children questions from an early age (Neale et al., 2020; Rowe et al., 2017; Yu et al., 2019) and in many cases, these questions support children's language development (e.g., Ard & Beverly, 2004; Muhinyi & Rowe, 2019; Rowe et al., 2017) and STEM learning (e.g., Haden et al., 2014). When caregivers ask questions, they model how to ask questions (Berlyne & Frommer, 1966), prompt children to provide a response (Shatz, 1987), and lead children to ask deeper questions (Rosenshine et al., 1996). Adult-posed questions also help children recall information; one study found that mothers who were taught to use an elaborative communication style, which emphasized the use of *wh-* questions, prompted children to recall more details of a camping activity than children whose mothers did not receive training (Boland et al., 2003).

Children's questions are also valuable for their learning. From an early age, children ask questions about a wide variety of topics (e.g., Chouinard et al., 2007; Callanan & Oakes, 1992; Grief et al., 2006; Ronfard et al., 2019), including sophisticated questions about causation (i.e., "why" or "how" questions; Callanan & Oakes, 1992). Children's questions address where they need more information, as they present their queries to people who can provide informative content (Berlyne & Frommer, 1996). At its core, question-asking keeps children engaged by allowing them to *direct their own learning* (Choi et al., 2018; Rosenshine et al., 1996) as they can learn more about a topic they are interested in, while also showing adults what more they would like to learn.

Based on research demonstrating the benefits of adults' and children's questions, recent efforts strive to increase inquiry in one educational domain in particular: STEM (science, technology, engineering, and mathematics) learning (e.g., Herrenkohl et al., 2011; Lucas et al., 2005; Richardson et al., 2012). Curiosity and question-asking are at the heart of STEM instruction, which relies on asking scientific questions to form hypotheses (see Klahr et al., 2011 for a review). Children are naturally curious about scientific domains (Bustamante et al., 2018; Jirout & Zimmerman, 2015). When they become uncertain of something, they deal with it by asking questions. Callanan and Jipson (2001) maintain that "explanatory conversations," discussions that include "why" questions and causal explanations, are key to children's scientific learning (p. 22). Caregivers can provide causal explanations for children's explanatory questions (Kurkul & Corriveau, 2017), facilitating children's scientific learning and encouraging further inquiry. By asking and answering questions, children can discover how things work and why things happen, fueling curiosity and STEM learning.

Although questions can support scientific reasoning and STEM learning (Haden et al., 2010), different barriers can affect parents' and children's question-asking. When *interaction* is limited between parents and children, rich bouts of question-asking are unlikely. Media use, either by adults or children, is one factor that can reduce parent-child interaction and conversation. One study found that parents asked their 3-year-olds significantly fewer questions when they interacted with shapes on a tablet application than when they played with concrete versions of the shapes (Neale et al., 2020). Another study suggests parents ask their preschoolers fewer questions when they are using a cell phone than when they are undistracted ([Author], under review).

Another factor that may affect adults' question-asking is a lack of knowledge about the value of questions. In museum contexts, adults may need prompting to ask their children deep, meaningful questions about exhibits. Providing adults with instructions about conversation before entering an exhibit can increase the number of *wh-* questions parents ask their children (Benjamin et al., 2010; Haden et al., 2014). Haden and colleagues (2014) increased adults' questions in a STEM-related museum exhibit through a brief question-asking training. Without instruction, European-American parents asked, on average, 3.60 *wh-* questions to their children; parents who received the training nearly doubled that number, asking an average of 6.91 questions (SD = 5.18). Although the intervention was effective, this approach required a live adult to facilitate trainings; other parents, who only viewed signs promoting question-asking, did not demonstrate increased question-asking. Perhaps generalizability of these strategies could be enhanced by *combining* signage with elements of the learning environment intentionally designed to promote parent-child interaction. For example, activities in the environment may require playfully working together or reading instructions. In other research, signage has been successful in eliciting conversation and questioning (e.g., Ridge et al., 2015). Hanner et al. (2019), for example, placed signs encouraging math talk between parents and children in grocery stores (e.g., "How many eggs are in a carton?"). Naturalistic observations revealed that math signage led to more math-related conversations between parents and children than conditions of no signage or non-mathematical signage (e.g., "What animal lays eggs?").

Barriers to question-asking extend beyond parent-child contexts. Even in the classroom, research suggests students and teachers ask few high-level, deep questions (Chin & Osborne, 2008; Engel, 2009; Humphries & Ness, 2015). Encouraging children to ask questions about STEM topics in schools may be difficult for a variety of reasons. Although children might think of a question, they may not have the confidence to express it aloud (Dillon, 1988). Additionally, children might assume their role in the classroom is to *answer,* but not *ask* questions, as the teacher typically poses questions for children to answer (Cazden et al., 2001). Especially surprising, one study reported that when asked to generate questions, some children in a Head Start preschool were not sure what a question was or maintained that they had already asked questions when they had actually made statements (Nayfield, 2014). Even if children have the confidence and knowledge to ask a question, students may lack curiosity in school, leading them to ask fewer genuine, deep questions (Engel, 2009). When elementary students were asked "What are you usually curious about?", only 17% of their accounts referenced experiences in school (Post et al., 2018). Further, teachers do not typically utilize strategies known to encourage curiosity, such as prompting students to generate their own questions (Jirout et al., 2018).

Given children's lack of questioning in schools, *Playful Learning Landscapes* targets time children spend *outside* of school, which comprises a stunning 80% of their waking hours (Meltzoff et al., 2009)—to provide playful learning opportunities grounded in evidence from developmental and education sciences (Bustamante et al., 2019). These installations are an innovative series of projects that redesign everyday spaces to promote the kind of caregiver-child interactions and question-asking that lead to learning (Hassinger-Das et al., 2018).

Parkopolis—the life-sized board game for STEM learning—is a recent example of a Playful Learning Landscapes installation tested in a children's museum for its potential to elicit STEM conversation and interactions between children and caregivers (Bustamante et al., 2020). Parkopolis challenges children with various playful activities—informed by research in early STEM education—such as dice with whole numbers and fractions (e.g., rolling "2 and ¼" to move 2 ¼ spaces on the board), a giant ruler for measurement games, a hopscotch game to challenge children's cognitive flexibility and inhibition, a shape zone that targets early geometry, and music pipes of various heights that prompt pattern recognition and working memory (see Figure 1 and Appendix). Parkopolis also emphasizes the value of asking questions and using STEM language through strategic signage (see Figure 1). Without in-person training or facilitation, conversation and question-asking are encouraged through the design of the environment, which scaffolds caregiver-child interaction as families proceed through the game. In many cases, for example, adults are needed to read instructions and game cards for children who are pre-literate. Beyond reading for children, caregiver scaffolding is typically needed to support especially younger children in navigating the game. For example, adults often keep children on task, reminding them to roll the fraction dice, proceed to the appropriate space on the board, and to take turns. Beyond the more formal board game, certain elements lend themselves well to *guided play*, a type of play in which adults have a learning goal in mind, but allow children to lead the interaction (Weisberg et al., 2013). The open-ended nature of activities in Parkopolis (e.g., giant ruler, music pipes) allow children to spontaneously and creatively interact with elements that are interesting to them, while adults can guide children towards a learning goal. For example, a child may run to the shape zone and begin hopping from shape to shape. While still allowing the child to take the lead, adults can provide educational scaffolding, naming different shapes and asking questions about shapes' names and properties.

These instances of scaffolded guided play may also prompt children and adults to respond to each other's questions—by allowing children to lead the interaction, children are likely to be attentive to the activity and responsive to questions. Further, in Parkopolis, specifically, adults and children often *need* to respond to questions to proceed with the game, for example, by answering game cards to advance forward or by responding to a query about the dice to inform an adult how many spaces they need to move.

Bustamante and colleagues (2020) reported that children and caregivers playing in Parkopolis used more whole number, fraction, reasoning, and pattern language compared to a STEM-focused control exhibit at the same museum where children launched foam rockets. Further, adults in Parkopolis used cell phones less frequently than adults in the control exhibit, which may have led to more caregiver-child interaction. Caregivers were also more likely to ask questions in Parkopolis than in the STEM control exhibit. However, the *content* of those questions was neither coded nor explored. Were children communicating their curiosity about *STEM* topics, and producing questions that are typically lacking in children's questioning? Were caregivers, too, asking children questions about STEM-topics, maximizing opportunities for learning? Additionally, exploring children's *responses* to questions is of value, as answering questions can help children remember more about parent-child activities (Hedrick et al., 2009). Utilizing a unique sample—distinct from Bustamante et al. (2020) —this study extended that work by analyzing the frequency and content of caregivers' and children's STEM-related questions in an exhibit intentionally designed to promote this type of questioning.

This study explored caregivers' and children's STEM-related questions in Parkopolis (i.e., experimental group) and a STEM-themed control exhibit, guided by the following hypotheses:

1. Caregivers and children will ask more questions overall in Parkopolis than the control, as Parkopolis's signage and interactive nature promotes question-asking.
2. Beyond an increase in questions overall, caregivers and children will also ask more *STEM-related* questions (i.e., math, spatial, and scientific thinking topics), which are

typically scarce in adult-child conversation (e.g., Chin & Osborne, 2008), in Parkopolis than the control because of the interactive design elements of Parkopolis.

3. Children and caregivers will *respond* to a higher proportion of each other's questions, as the nature of the game stimulates back-and-forth interaction and conversation.

Method

Participants

Two hundred and fourteen groups of caregivers and children (n = 107 in Parkopolis) visiting two exhibits in the Please Touch Museum in Philadelphia, PA were observed. Children ranged in age from less than one year old to an estimated age up to 12-years-old. Although children may ask questions as early as 2-years-old (e.g., Ronfard et al., 2018), younger children's questions were difficult to code reliably using the methods of this study. Therefore, any group that did not have at least one child estimated to be above the age of 2 was excluded from analyses, in an effort to preserve coding reliability. After excluding groups without a child estimated to be above the age of 2, the final sample included 197 groups (n= 93 in Parkopolis). No demographic information beyond approximate ages and genders were collected. Groups included 280 adults (190 female) and 333 children (159 female). The average estimated age of children was 4.29 years (*SD*= 1.97). Separate *t*-tests revealed no differences in demographics between the two conditions (Table 1). All observations took place between July and August 2018, during weekdays. This study, titled "[City blinded] Playful Learning City" was approved by the [Institution blinded] IRB, protocol #24,532. Note that there is potential overlap between the two exhibits, as families could have gone from one exhibit to the other while visiting the museum. However, as previous research (Bustamante et al., 2020) on these exhibits suggested, there is no reason to suspect systematic differences in which exhibit families would visit first; the exhibits are in opposite corners of the museum with the same room size, layout, and approximately the same distance from the museum entrance.

Procedure

Researchers observed families discretely as they walked through Parkopolis or the control exhibit, which consisted of two launching stations where children could charge and launch foam rockets through spinning rings hanging from the ceiling (Figure 1; Appendix). Critically, this control was also STEM-themed in nature, and contained ample opportunity for spatial, mathematical, and scientific language. For example, families could discuss how many foam pieces were needed to form a rocket, describe the trajectories of the rockets using spatial language, and make observations about the effect of air pressure on the rockets' launch heights. However, no signage was present in the room and, in many cases, children could engage with the exhibit without adult assistance. For detailed descriptions of the two exhibits, see Bustamante and colleagues (2020). Observations ranged between 2 and 5 minutes per group, although groups often continued to play in the exhibit longer than observation periods. These cycles started when families entered the exhibit and ended when either families left the exhibit or 5 minutes had passed. Families that played in the exhibits for less than 1 minute were not included. Although some families may have realized that researchers were observing them, efforts were made by the research team to go unnoticed by the exhibit visitors. Specifically, researchers walked around the exhibit wearing casual clothing (e.g., sneakers, jeans, etc.) and unobtrusively took notes in a notepad. Further, we used the same observational methods in both exhibits, so any effects should be equal across conditions. Each researcher spent half of her time observing in Parkopolis and half in the control exhibit. On average, observation cycles were 3.77 minutes (SD= 1.25). Observation cycles were significantly longer in the control (M= 3.95, SD= 1.22) than Parkopolis

(*M*= 3.56, *SD*= 1.26), *t*(195)= -2.22, *p*= .028. As a result, analyses controlled for time spent in the exhibit.

While observing families, researchers recorded the questions and ensuing responses (verbal or nonverbal) from both caregivers and children interacting in the exhibits. Before independently recording questions, each researcher double-coded observations with the first author for at least 30 minutes, or until their recordings matched the first author's consistently. After training, researchers independently recorded questions and responses by writing conversations with paper and pen.

Coding

After observations were completed, questions were coded as information-seeking (i.e., probe for facts or explanations) or non-information-seeking (Chouinard et al., 2007). The latter, questions such as "Can you pick me up?", were not coded further. Information-seeking questions were further coded under one of four topics (Bustamante et al., 2020; see Table 2). *Mathematical* included questions about whole numbers, fractions, and the concept of more and less. *Spatial* included questions about sizes, features, directions, shapes, and measurements. S*cientific thinking* included questions about patterns, observations, explaining, and making predictions. Lastly, *non-STEM* topics included questions that were unrelated to mathematical, spatial, or scientific topics. A second coder, blind to hypotheses, reviewed the transcribed questions and responses and recoded 20% of the data. Reliability was high, IRR= .85 (Miles & Huberman, 1994).

Responses to information-seeking questions were given a code of 1 for any response, verbal or nonverbal (e.g., nodding head), while a lack of response was coded as a 0. Analyses first assessed both verbal and nonverbal responses combined and then were repeated with verbal-only responses. For caregivers and children, analyses considered the proportion of information-seeking questions which received a response.

Results

Diagnostic tests revealed that neither caregivers', nor children's information-seeking or STEM-related questions met the assumptions for linear regression, as the distribution was heavily skewed to the right. Additionally, a high number of zeroes were observed, as many groups did not ask any questions (see Figure 3 and Tables 3 and 4). As a result, Poisson regressions were employed to predict the number of STEM questions in the two exhibits (Tables 5-7). To control for the amount of time groups played in exhibits, time was entered as a predictor in all models. Further, we controlled for the number of male and female adults in the group, as well as the average child estimated age in each group. We did not control for child gender, as initial correlations revealed no relationship between the number of boys or girls in a group and adults' and children's questioning (*ps* > .060). Exponentiated beta coefficients are reported for ease of interpretation.

To test our first question, whether caregivers and children asked more information-seeking questions overall in Parkopolis than the control, two Poisson regressions were employed. After controlling for time, number of males and females, and average child age, caregivers asked more questions in Parkopolis than in the control ($\beta = .41$, $p < .001$). Similarly, after controlling for the same variables, children also asked more in Parkopolis than in the control ($\beta = .59$, $p = .014$).

To test our second hypothesis, STEM-related questions were analyzed between the two conditions. The first model (adults' math questions) revealed that, after controlling for time, number of male and female adults, and child age, adults asked significantly more math questions in Parkopolis than in the control (β= ..06, $p < .001$). The second model (adults' spatial questions) revealed that, after controlling for the same variables, caregivers also asked significantly more spatial questions in Parkopolis than in the control (β= .24, $p < .001$). The third model (adults' scientific thinking questions), controlling for these same variables, revealed that adults' scientific thinking questions did not differ by condition, (β= .74, $p = .267$).

Next, children's spatial and scientific thinking questions were compared between conditions using two separate Poisson regressions. These questions were not necessarily in response to adults' STEM-related questions and in many cases, were asked spontaneously. No model was conducted for children's mathematical questions, as there were none observed in the control, although 20.11% of children's information-seeking questions were about mathematical topics in Parkopolis. The first model (children's spatial questions) revealed that, after controlling for time, number of male and female adults in each group, and child age, children asked a similar number of spatial questions in the two conditions (β= .47, $p = .181$). The second model (children's scientific thinking questions) revealed that, after controlling for the same variables, children also asked a similar number of scientific questions in the two conditions (β= .50, $p = .105$). Due to a low frequency of child STEM questions in the sub categories (0.06-0.16% of all questions), we collapsed them into one code. A Poisson regression found that, when controlling for these same variables, children in Parkopolis asked more STEM-related questions than children in the control ($\beta = .35$, $p = .001$).

To test our third hypothesis, children's and caregivers' *responses* to questions were analyzed with two independent-samples Mann-Whitney U tests (due to bimodal distributions). Children responded to a significantly higher proportion of adults' information-seeking questions in Parkopolis ($M = .49$, $SD = .42$) than in the control ($M = .27$, $SD = .40$), $U = 2{,}232.50$, $z = 2.92$, $p =$

.004. Adults' responses to children's information-seeking questions did not differ by condition (Parkopolis: *M*= .70, *SD* = .41; Control: *M*= .60, *SD*= .46), *p*= .499. When considering only *verbal* responses, children still responded more to adults' information-seeking questions in Parkopolis than in the control, *U*= 2,2124.00, *z*= 2.68, *p*= .007. Adults' verbal responsiveness did not differ between exhibits, *p*= .658.

Discussion

Parkopolis successfully encouraged STEM question-asking from caregivers and children. Critically, the control in the current study was stringent; like Parkopolis, the control was a STEM-themed exhibit and contained many opportunities for STEM-related talk. Yet, groups still asked more STEM-related questions in Parkopolis than in the control. Beyond demonstrating that families use STEM-related talk in Parkopolis (Bustamante et al., 2020), our findings provide new evidence that Parkopolis also provokes STEM-related questioning. The current study suggests that designing informal learning spaces *intentionally* to promote questioning can increase adults' and children's STEM-related questions.

Parkopolis demonstrates how informal learning environments can foster children's curiosity. In schools, children as young as kindergarten face stressful assessments of learning and are given less time for play than in the past (Bassok et al., 2016). However, in a life-sized board game, children are free to learn playfully, through exploring and experimenting with different components of the installation and asking questions. Although we did not assess learning, the hands-on, active nature of the exhibit may especially promote learning (Hirsh-Pasek et al., 2015) because children are following their own interests in framing their questions. Informal learning environments, like Parkopolis, are thus especially strong contexts to study children's question-asking. Some of the research on young children's question-asking already exists outside of the classroom. Chouinard et al. (2007), for example, studied children's question-asking in zoos and found that children asked more questions about biological phenomena when viewing live animals than when viewing drawings or replicas of animals.

We hypothesize two reasons for why Parkopolis was successful in promoting question-asking: 1) signage suggesting the value of questions, and 2) the interactive nature of the board game, which promoted adult involvement and, in some cases, required conversation about STEM topics to proceed through the game. Signage has been used effectively in other places where parents and children go (Hanner et al., 2019; Ridge et al., 2015; Song et al., 2017). Song et al. (2017), for example, used signs in a children's museum, with the aim of changing parents' beliefs about educational opportunities in a museum exhibit. Parents who viewed signs, which provided exhibit ratings for learning domains such as language and literacy and science, rated the presence of learning opportunities in exhibits more similarly to experts.

In the current study, signage may have encouraged STEM-related talk and question-asking (Figure 2) in comparison to the control exhibit, which although STEM-themed, did not include such signage. As in Hanner et al. (2019), the question sign may have prompted caregivers to use some of the question stems from the sign (i.e., *why, how, who*), leading to increased question-asking. Additionally, as in Song et al. (2017), the signs may have suggested to caregivers that the exhibit offered educational opportunities. Although caregivers asked more questions in an exhibit that explicitly prompted the use of questions, it is intriguing that a simple sign could increase questioning, a behavior that is difficult to promote in schools and has required in-person training in other studies of museum exhibits (e.g., Haden et al., 2014). Interestingly, these results are in contrast to Haden and colleagues' (2014) study, which found signs were *ineffective* in promoting parents' question-asking in a STEM exhibit. Although the caregivers in our sample asked fewer questions overall than those in Haden et al. (2014), caregivers did ask more questions in Parkopolis than in the control in the current study. Further, observation time in Haden et al., (2014) was 7 to 12 minutes longer than observation time in the current study. Regardless, the contrasting findings raise the possibility that perhaps signs, alone, are not sufficient to encourage parental questioning. Instead, the intentional design of the *entire* informal learning space may play a key role in parent-child interaction.

Beyond signage, Parkopolis included elements that encourage parent-child interaction. For example, children's increased responsiveness to adults' questions in Parkopolis suggests the exhibit encouraged more conversation than the control. In Parkopolis, adults often needed to interact with children to help them understand the game, interpret fractions, and, in some cases, read game cards. From a Vygotskian perspective, the exhibit prompted parent scaffolding to help children complete various STEM-related activities (Vygotsky, 1978). One of the ways caregivers likely scaffolded their children's activity was through question-asking. The control exhibit, however, did not always require adult involvement; many children could launch the rockets without adult scaffolding. Further, previous research on these exhibits found that adults used their cell phones less in Parkopolis compared to the control exhibit (Bustamante et al., 2020). Adult cell phone use can affect parents' question-asking and children's language learning (Reed et al., 2017; [Author], under review). Limited cell phone use in Parkopolis may have led to greater question-asking by both parents and children.

Crucially, Parkopolis was located within a children's museum that required paid admission. However, other informal learning environments, which are accessible to most families, such as grocery stores, doctors' offices, bus stops, train stations, and laundromats, can also benefit from this research. Adding signs, such as the question-themed sign in Parkopolis, to these everyday spaces, may promote question-asking between caregivers and children. Furthermore, including interactive elements in informal spaces, such as game cards with questions about science and math, may encourage communication between adults and children, potentially leading to greater question-asking. Although not every informal learning environment can include all elements of Parkopolis, many of these spaces can use the principles of Parkopolis to promote curiosity and question-asking.

Importantly, although STEM question-asking was higher in Parkopolis, STEM questioning was still relatively low overall. Further, questions about causal explanations (i.e., *why* and *how* questions) were especially rare: only seven caregivers (four in Control, three in Parkopolis) and twelve children (six in each exhibit) asked a "why" or "how" question. Given these explanatory questions are linked to STEM learning (Callanan & Jipson, 2001), researchers might consider ways to further increase these behaviors. Questions about these topics may be increased by additional signage prompting queries. For example, Ridge et al. (2015) placed a total of *four* signs in grocery stores to prompt question-asking and answering between parents and their children.

Some limitations in this research should be considered. First, the observational researchers were not fully blind to the purposes of the study. Although the researchers were not all aware of the specific hypotheses of the study, they were knowledgeable about the general study purpose to compare question-asking across the two exhibits. Additionally, the lack of detailed demographic characteristics (i.e., race, income, etc.) limits the generalizability of the findings across other informal learning spaces and populations. Children's museums, unlike supermarkets, likely attract families that have the resources to pay the price of admission. Therefore, future research should test the efficacy of Parkopolis for prompting question-asking in other settings and populations (e.g., a public park) though it has already been shown that conversation between parents and children from low income families can be promoted through signage, e.g., Ridge et al., 2015. Future research might consider alternative methods, such as asking parents for demographic information after visiting the exhibit, to better assess how these factors affect question-asking. Additionally, as families were not randomly assigned to condition, there could be differences between the families who are drawn to one exhibit over the other. However, as both exhibits were STEM-focused, this possibility is unlikely. Limitations specifically associated with museum research should also be considered. For example, within the two exhibits, visitors could have had different experiences due to choosing to engage with different elements. Similarly, the exhibits could have been altered by high traffic throughout the day. Pieces of foam rockets in the control exhibit, for example, could be scattered or damaged in the room after multiple families had played.

Conclusion

The current research suggests that simple features of an informal learning environment can promote question-asking. Despite the fact that the control exhibit included many engaging elements that could, in theory, promote children's curiosity, both children and adults asked few questions in that exhibit. Parkopolis created an environment that invited adult involvement, and in some cases required adult support. It yielded parental scaffolding and question-asking, suggesting that caregivers and children can be encouraged to ask questions about STEM topics that build children's questioning, science, spatial, and math skills.

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Tables

Table 1.

Demographic information for sample; Means (standard deviation); p-values for condition comparisons were obtained using independent-samples t-tests

	Total Sample	*Parkopolis*	*Rocket-Launching Control*	*Condition comparisons*
Number of adults in group	1.42 (0.67)	1.50 (0.70)	1.34 (0.63)	p = .077
Number of children in group	1.69 (0.96)	1.77 (1.03)	1.61 (0.88)	p = .247
Number of female adults in group	0.96 (0.51)	1.01 (0.48)	0.92 (0.53)	p = .228
Number of male adults in group	0.46 (0.56)	0.50 (0.58)	0.41 (0.53)	p = .249
Number of girls in group	0.81 (0.84)	0.85 (0.92)	0.77 (0.77)	p = .505
Number of boys in group	0.88 (0.78)	0.92 (0.89)	0.85 (0.66)	p = .480
Child age	4.29 (1.97)	4.03 (1.60)	4.52 (2.24)	p = .084

N = 197, (n = 93 in Parkopolis, n = 104 in control); only children estimated to be above 2 years are included

Table 2.

Examples of each question topic. Note that sizes (Spatial) and explaining and making predictions (Scientific Thinking) are not listed, as no questions asked fell under these codes

	Adult Questions	*Child Questions*
Math Questions		
Whole Numbers	So, what's 3 and 6? (adding whole numbers)	Which one is more- 6 or 8? (comparing whole numbers)
Fractions	Where's 3/4's come in? (interpreting fraction on dice)	N/A
More and Less	Which side is more? Red side or blue side? (comparing circles on game card)	Which side is less? (comparing circles on game card)
Spatial Questions		
Features	Is that flat? (describing shape)	N/A
Directions	Turn it the other way, does that do anything? (asking about direction of turn)	Which way does it spin? (asking about direction of turn)
Shapes	Where's the circle? (identifying shape)	Is that a pyramid? (identifying shape)
Measurements	Is that one higher or lower? (comparing heights)	What's 4 inches? (asking about measurement terms)
Scientific Questions		
Patterns	Can you play that pattern (on the music tubes)? (prompting pattern recognition)	Who's turn is it now? (noticing the pattern of the game)
Observations	See how she's moving the ball up? (observing ball movement)	Do you hear that, Dad? (observing sound)
Non-STEM Questions	Do you have to go to the bathroom?	Can I play again?

Table 3.

Frequencies for adults' and children's questions

	Full Sample	*Parkopolis*	*Control*
Number of adult information-seeking questions	293	264	163
Number of child information-seeking questions	164	85	79
Number of groups with no adult questions	54	18	36
Number of groups with no child questions	113	53	60

N = 197, (n = 93 in Parkopolis, n = 104 in control)

Table 4.

Questions by STEM topic in Parkopolis and control; Mean (standard deviation)

	Parkopolis	*Control*
Adult Questions		
Information-Seeking	2.11 (2.14)	0.93 (1.16)
Math	0.77 (1.15)	0.05 (0.26)
Spatial	0.45 (1.07)	0.12 (0.39)
Scientific	0.33 (0.82)	0.25 (0.53)
Child Questions		
Information-Seeking	0.57 (1.04)	0.40 (0.76)
Math	0.12 (0.44)	0.00 (0.00)
Spatial	0.09 (0.28)	0.06 (0.27)
Scientific	0.17 (0.56)	0.10 (0.30)

N = 197, (n = 93 in Parkopolis, n = 104 in control)

Table 5.

Regression table for Poisson regression analyses predicting adults' and children's information-seeking questions; SE refers to standard error

	Unstandardized	*SE*	Exponentiated (β)	*p*-value
Model 1: Adult Information-Seeking Questions				
Condition	.89	.13	.41	< .001
Time	.35	.05	1.42	< .001
Child Avrg. Age	-.04	.03	.96	.209
Number Female Adults	.28	.12	1.32	.018
Number Male Adults	0.04	.10	.96	.728
Model 2: Child Information-Seeking Questions				
Condition	.53	.21	.59	.014
Time	.22	.09	1.25	.013
Child Avrg. Age	.08	.05	1.09	.096
Number Female Adults	-.35	.22	.71	.111
Number Male Adults	-.13	.20	.88	.534

N = 197, (n = 93 in Parkopolis, n = 104 in control); Condition: Parkopolis = 1, Control = 0

Table 6.

Regression table for Poisson regression analyses predicting adults' STEM-related questioning; SE refers to standard error

	Unstandardized	*SE*	Exponentiated (β)	*p*-value
Model 1: Adult Math Questions				
Condition	2.85	.47	.06	< .001
Time	.45	.11	1.58	< .001
Child Avrg. Age	-.02	.07	.98	.809
Number Female Adults	.44	.22	1.55	.045
Number Male Adults	.16	.18	1.18	.362
Model 2: Adult Spatial Questions				
Condition	1.41	.32	.24	< .001
Time	.36	.12	1.43	.004
Child Avrg. Age	-.17	.08	.84	.038
Number Female Adults	-.10	.31	.90	.749
Number Male Adults	-.47	.28	.62	.086
Model 3: Adult Scientific Thinking Questions				
Condition	.30	.27	.74	.267
Time	.40	.13	1.50	.001
Child Avrg. Age	-.08	.07	.92	.295
Number Female Adults	.45	.24	1.57	.066
Number Male Adults	.39	.21	1.47	.065

N = 197, (n = 93 in Parkopolis, n = 104 in control); Condition: Parkopolis = 1, Control = 0

Table 7.

Regression table for Poisson regression analyses predicting children's STEM-related questioning; SE refers to standard error

	Unstandardized	*SE*	Exponentiated (β)	*p*-value
Model 1: Child Spatial Questions				
Condition	.75	.56	.47	.181
Time	.55	.29	1.74	.055
Child Avrg. Age	.02	.14	1.03	.851
Number Female Adults	-.89	.56	.41	.113
Number Male Adults	.012	.56	1.01	.983
Model 2: Child Scientific Thinking Questions				
Condition	.68	.42	.50	.105
Time	.10	.16	1.10	.542
Child Avrg. Age	.19	.09	1.20	.045
Number Female Adults	-.06	.36	.94	.869
Number Male Adults	.45	.33	1.57	.175
Model 3: Child STEM (combined) Questions				
Condition	1.05	.31	.35	.001
Time	.24	.12	1.27	.052
Child Avrg. Age	.13	.07	1.14	.059
Number Female Adults	-.43	.27	.65	.107
Number Male Adults	.42	.25	1.52	.098

N = 197, (n = 93 in Parkopolis, n = 104 in control); Condition: Parkopolis = 1, Control = 0

Appendix

Elements in Parkopolis (Bustamante et al., 2020)

1. *Fraction dice and game board spaces*: The fraction dice include one die with the familiar whole numbers, 1-6, and a second die divided into quarters (1/4, 2/4, 3/4, and 4/4). The game board spaces represent a number line, with each space divided by tick marks into fourths.
2. *Game cards*: Some game board spaces direct children to choose a game card. These cards challenge children with a variety of tasks including numeracy, spatial, physical, and fluid reasoning activities.
3. *Pattern pipes*. These colored pipes make different sounds when struck. Some game cards challenge children to follow patterns with these pipes.
4. *Life-sized ruler*: This ruler is placed on the floor to allow children to practice measurement, for example, by measuring the distance of their jumps.
5. *Executive functioning hopscotch*: This hopscotch board is placed on the floor and challenges children to use cognitive flexibility. Children have to follow a random pattern of footsteps on the hopscotch board and are challenged to remember rules (e.g., use one foot when the board shows two feet).
6. *Shape zone*: This floor feature includes various shapes (e.g., triangle, square) of different sizes and colors. Some game cards prompt children to jump on specific shapes.
7. *Planning dots*: These dots are scattered on the floor of the exhibit. Cards prompt children to plan and communicate with others to execute patterns.

Elements in rocket-launching control (Bustamante et al., 2020)

1. *Foam rockets*: In the middle of the roam, foam pieces were placed in a bucket. Children could assemble these pieces into foam rockets.
2. *Launching stations*: These two areas allow children to launch foam rockets into the air. Children press a button to create air pressure and then press a second button to launch the rocket.
3. *Rotating rings*: While launching the rockets, children can aim the launcher to attempt to launch their rocket through large rotating rings hanging from the ceiling.
4. *Space shuttle replica*: A large space shuttle with buttons and levers allows children to engage in dramatic play.
5. *Rocket activity*: Children can pull a lever, located on a large transparent rocket, to release a ball and watch it roll down a track.