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More Than Just a Game: Transforming Social Interaction and STEM Play With Parkopolis

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Science, technology, engineering, and math (STEM) focused language and interactions build a foundation for later STEM learning. This study examines the ability of the life-size math and science board game “Parkopolis” to foster STEM language and interaction in young children and their families. This study is part of a larger initiative called Playful Learning Landscapes that aims to create playful learning opportunities for children and families in the places they naturally go. Observational results from 562 families suggest that caregivers and children in Parkopolis demonstrated greater STEM language, engagement, interaction, and physical activity compared to a STEM focused traditional children’s museum exhibit. Implications and next steps are discussed in regards to maximizing the number of families that can benefit from Parkopolis’ playful STEM learning opportunities.

Keywords: STEM education, playful learning, embodied learning, caregiver–child interaction, life-size board game

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Science, technology, engineering, and mathematics (STEM) are rich content areas that provide children an opportunity to engage in the scientific inquiry process and experience high-quality learning opportunities (Bers, Seddighin, & Sullivan, 2013; Bustamante, Greenfield, & Nayfeld, 2018; Clements & Sarama, 2015; Schmitt, Korucu, Napoli, Bryant, & Purpura, 2018). Research demonstrates that early STEM education relates to not only later STEM outcomes but important domain-general skills such as executive functioning, approaches to learning, and fluid reasoning, which are integral to later school success (Bustamante, White, & Greenfield, 2017; Green, Bunge, Briones Chiongbian, Barrow, & Ferrer, 2017; Nayfeld, Fuccillo, & Greenfield, 2013). Accordingly, national early learning standards now emphasize the importance of STEM education. For example, Head Start recognizes science and math as core school-readiness domains in their early learning framework (U.S. DHHS, 2015). There is no question that high-quality formal STEM education represents a powerful vehicle for promoting STEM learning. Yet, children spend only 20% of their waking hours in school (Meltzoff, Kuhl, Movellan, & Sejnowski, 2009).

Tremendous opportunity remains to supplement school-based formal STEM learning in informal contexts outside of school. Research on informal STEM learning demonstrates that playful enrichment activities (e.g., puzzles, block play, board games, chil-

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dren's museums) and conversations between caregivers and children that include STEM language during play or informal interactions build a strong foundation for STEM learning by fueling children's understanding of spatial, scientific, and mathematical language (Davis, Cunningham, & Lachapelle, 2017; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Gunderson & Levine, 2011; Pruden, Levine, & Huttenlocher, 2011; Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011).

Further, cities are ripe for informal STEM learning interventions due to their dense population, racial and ethnic diversity, and high representation of low-income families. With global trends of urbanization, it is estimated that 70% of children will reside in cities by the year 2050 (United Nations, 2012). Thus, urban public spaces offer an ideal platform for promoting playful STEM learning opportunities by bringing developmental science into the world (Golinkoff, Hirsh-Pasek, Grob, & Schlesinger, 2017). A series of public installations called "Playful Learning Landscapes" (PLL) combine urban revitalization with the science of learning to promote high-quality caregiver–child interactions and learning opportunities for children and families (Bustamante, Hassinger-Das, Hirsh-Pasek, & Golinkoff, 2018; Hassinger-Das, Palti, Golinkoff, & Hirsh-Pasek, 2019; Schlesinger, Hassinger-Das, Zosh, Golinkoff, & Hirsh-Pasek, 2020). In this study, we present "Parkopolis" as the latest PLL installation comprising a life-sized board game to examine its effects on enhancing the kinds of adult–child talk and interactions known to stimulate math and science learning.

Parkopolis: The Life-Size Board Game for Math and Science Learning

Children learn best in actively engaging, meaningful, iterative, and socially interactive settings — making play an ideal context to foster learning and development in and out of school (Hirsh-Pasek, Golinkoff, Gray, Robb, & Kaufman, 2015; Zosh et al., 2018; Yogman et al., 2018). Parkopolis is a life size board game crafted to provide embodied learning opportunities in a playful and physically active context (see Figures 1 and 2 and Figures S1 and S2 in online supplementary materials). Elements are designed into the game architecture using research in the science of learning to stimulate particular kinds of parent–child interactions that support learning (further detailed in the Method section). For example, research suggests that fractions are a stumbling block for children starting in 3rd grade (Booth & Newton, 2012). Perhaps introducing fractions and fraction language earlier in a playful context would familiarize children with fractions and help them overcome this common roadblock. Thus, in Parkopolis, children roll refashioned dice that represent both whole numbers and fractions (see Figure 2) to advance around a 30 square foot board full of whole numbers and fractions and draw cards that suggest challenges and seven unique activities born directly from literature on STEM education (Dackermann et al., 2016; Diamond & Lee, 2011; Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Link, Moeller, Huber, Fischer, & Nuerk, et al., 2013; Scalise, Daubert, & Ramani, 2018; Schmitt et al., 2018; Siegler & Ramani, 2008; Ramani & Scalise, 2018). Games are a powerful tool for learning academic skills outside of school (Hassinger-Das et al., 2017) and Parkopolis was designed to provide developmentally appropriate activities for children from early childhood through primary school.

Figure 1. Parkopolis game board. See the online article for the color version of this figure.

Figure 2. Parkopolis fraction dice. See the online article for the color version of this figure.

Playful Learning Landscapes

Parkopolis, as an installation of the Playful Learning Landscapes initiative, lies at the juncture of the science of learning and the global cities movement, embedding informal learning opportunities in urban hubs and into the places where families naturally go. Insight into the potential benefits of playing Parkopolis comes from decades of literature in the science of learning (Dackermann et al., 2016; Diamond & Lee, 2011; Fisher et al., 2013; Link et al., 2013; Scalise et al., 2018; Schmitt et al., 2018; Siegler & Ramani, 2008; Ramani & Scalise, 2018) and has been embedded in previous PLL installations that have promoted precisely the kinds of caregiver–child interactions that fuel learning (Hassinger-Das et al., 2019). In "Supermarket Speak," for example, strategic signage was placed in grocery stores in low-SES neighborhoods, and a 33% increase in caregiver–child language interaction was observed when the signs were up, versus when the signs were down (Ridge, Weisberg, Ilgaz, Hirsh-Pasek, & Golinkoff, 2015). This study has since been replicated with signage that specifically targets math language (Hanner, Braham, Elliott, & Libertus, 2019).

Another PLL project, "Urban Thinkscape" placed playful learning installations (e.g., spatial puzzles and executive function hopscotch) at a bus stop and adjacent lot in a densely populated urban low-SES neighborhood and observed strong effects on families' conversational turns, numeracy language, spatial language, and overall interaction pre to post installation (Hassinger-Das et al., 2019) — precisely the language that was targeted by the activities. PLL activities are derived from the literature on education and development, and STEM learning opportunities are featured prominently in the installations. Overall, PLL activities show great promise for transforming spaces into learning opportunities for children with ripe opportunities for future studies to examine direct assessments of STEM outcomes and long-term benefits of these installations.

STEM Talk, Play, and Learning

Use of STEM language with young children anchors their later STEM learning (Levine et al., 2010; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2017). For example, Berkowitz and colleagues (2015), performed a randomized trial with nearly 600 first graders and showed that home-based math story-time activities that targeted parent–child math language and interaction significantly boosted children's math achievement across the school year compared to a reading only control condition. Similarly, Pruden and colleagues (2011) demonstrated that the amount of spatial language that parents use with their children (14 to 46 months old) at home predicted their later spatial skills at 54 months old. Given that spatial knowledge is a key underlying skill in math and science learning and predicts children's STEM success years later (Uttal & Cohen, 2012; Uttal et al., 2013; Verdine et al., 2017; Wai, Lubinski, & Benbow, 2009), efforts that effectively promote spatial and other STEM focused caregiver–child language and interaction have great potential to positively impact children's STEM development. Another study on 3- to 5-year-olds' mathematics and literacy skills uncovered that mathematical language skills mediate the relations between early mathematics and literacy skills (Purpura, Logan, Hassinger-Das, & Napoli, 2017), demonstrating that math performance may be directly dependent on children's mathematical language skills. Thus, in Parkopolis we ensured that elements of the game and the installations associated with it target key STEM skills like spatial learning, patterns, geometry, numeracy, and executive functions that predict later STEM outcomes (Clements & Sarama, 2014; Clements, Wilson, & Sarama, 2004; Green et al., 2017; Rittle-Johnson, Fyfe, Loehr, & Miller, 2015; Verdine et al., 2014).

Experimental and short-term playful learning interventions have demonstrated the power of informal learning contexts, social interactions, and guided play for boosting children's early math learning and skill development. In formal learning or direct instruction, children have little control over how they engage with their learning environment as this is generally dictated by the adult and the learning goals. In contrast, during free play, children are free to engage as they wish without any guidance on learning goals. Guided play activities are a mixture between formal learning and free play. They are designed based on a learning goal with scaffolds embedded in the learning environment or provided by an adult while allowing children to have large control over their play activities and learning (Zosh et al., 2018). Fisher et al. (2013), for example, demonstrated that 4- and 5-year-olds were more likely to learn early geometry concepts when being taught about the geometric properties of shapes in child-directed guided play rather than in direct instruction. This result surfaced immediately and remained a week later. Guided play in which a researcher and child engaged in role play and where children take the lead with an adult "coach" outperformed the 4 and 5-year old children in the free play and didactic instruction conditions when asked to identify typical and atypical triangles and pentagons. Similarly, caregiver–child play of a shape and color matching game at home significantly improved low-income prekindergarten children's shape knowledge (Ramani & Scalise, 2018). Playing War, a card game that integrates symbolic (i.e. numbers) with nonsymbolic representations (i.e. circles), allowed children to compare representations and then to decide the winner based on the higher magnitude. Such games reduced the gap between low-income and middle-income preschoolers in their ability to make these symbolic magnitude comparisons (Scalise et al., 2018).

There is evidence that the context and playful environment molds the amount and type of early math talk that children hear. In an experiment comparing math talk elicited by formal learning, guided play, and unguided play (e.g., free play) between parents and their 4- and 5-year-old children, the formal learning condition yielded the most math talk, whereas the guided play condition elicited more math talk than the unguided play condition. Parents did, however, consider the guided play condition more fun than the learning condition, which could motivate them to engage their children in play contexts in the long run (Eason & Ramani, 2018). Additionally, similar work has noted that board game play spurs more math talk than puzzles or math-based reading activities during low-income preschooler–caregiver interactions, but each activity elicits a different kind of math talk (Daubert, Ramani, Rowe, Eason, & Leech, 2018). Linear numerical board games promote children's math development (Siegler & Ramani, 2008; Skwarchuk, Sowinski, & LeFevre, 2014), and children learn more effectively when they engage with their whole body (Dackermann et al., 2016; Link et al., 2013) rather than in more receptive learning contexts. Such findings suggest that a life-sized board game targeting multiple aspects of STEM learning might give rise to a host of STEM skills while at the same time encouraging physical activity. While Parkopolis does not encompass all STEM skills, it represents a core subset of skills demonstrated in prior research to predict children's school readiness and later school success. Parkopolis was design to embed opportunities for fostering these skills in a playful and engaging context.

Current Study

Although the ultimate goal for Parkopolis is to install the game board outdoors in public space, the cost of building an outdoor version of the game with materials that can withstand the elements is significantly greater than that of creating and testing the concept in an indoor version. Therefore, to establish a proof of concept, this study was conducted at a local children's museum. The museum serves a wide range of children and families from different racial, ethnic, and socioeconomic backgrounds and attracts over 500 thousand visitors each year. The majority of children at the museum range from 2 to 7 years of age, although preschool (3–5 years old) is the most common age group. Parkopolis was an exhibit at

Figure 3. The Rocket Room control condition. See the online article for the color version of this figure.

the museum in the summer of 2018. To evaluate how the play and talk Parkopolis engendered compared to other exhibits, a similarly sized exhibit was selected as the control condition. The "Rocket Room," a STEM oriented exhibit, provided a variety of activities further detailed in the Method section and Figure 3.

The focus of this study was to examine: (a) the use of STEM language, specifically, language regarding whole numbers, fractions, spatial language, measurements, reasoning, patterns, prediction, observation, planning, and question asking; (b) caregiver and child engagement (low, moderate, or high level of engagement) and (c) physical activity (i.e. whether caregivers and children were sedentary, moderately active, or vigorously active); (d) technology use (amount of time spent on mobile devices); and (e) caregiver child interaction, specifically, the number of conversational turns, overall level of interaction (low, moderate, or high), caregiver communication style (directive or following the child's lead), and valence of interactions (negative, neutral, positive).

Hypotheses

Our study was guided by three hypotheses that compared behaviors and interactions in Parkopolis versus the Rocket Room, always controlling time in the exhibit, age, and gender. The first hypothesis (H1) focused on the caregivers. For H1, we hypothesized that in comparison to the Rocket Room exhibit, Parkopolis would relate to caregivers use of more STEM language, higher levels of engagement, physical activity, and decreased technology use. The second hypothesis (H2) focused on the children. For H2, we hypothesized that increased STEM language, engagement, physical activity, and decreased technology would be related to children who played Parkopolis compared to the Rocket Room. In the third hypothesis (H3), we expected that increased levels of interaction in Parkopolis as measured by conversational turns, overall level of interaction, caregiver communication style, and valence of interactions would be more strongly related when playing Parkopolis than when engaging with the Rocket Room exhibit.

Method

Internal Review Board (IRB)

This study, titled "Philadelphia Playful Learning City" was approved by the Temple University IRB, protocol #24,532.

Participants

The sample contained 562 groups or families consisting of at least one adult and at least one child. Of these, 349 groups were observed in Parkopolis, and 213 groups were observed in the Rocket Room. Of the 349 families observed playing Parkopolis, 74 stayed long enough to be observed for a second cycle and 12 families for a third cycle. Of the 213 families observed in the Rocket Room, 23 were observed for a second cycle and 4 families for a third cycle. All observations were conducted between May and August, 2018. For full estimated demographic information on study participants, see Table S1 (in online supplementary materials). Reliability statistics of the estimates are found in the Observer Training section below. Note that there is potential overlap between the Parkopolis and Rocket Room samples; if families visited both exhibits, they could have been observed in both conditions. However, no systematic differences in the pattern that families visited the exhibits are anticipated as they are in opposite corners of the museum with the same room size, layout, and approximately the same distance from the museum entrance.

Parkopolis Activities

Fraction dice and game board spaces. One of the goals of Parkopolis was to introduce the concept of fractions. Because children hear little about fractions in their everyday lives, they struggle to understand that a whole number can be broken into smaller components — or even that there are numbers smaller than one (Booth & Newton, 2012; Lortie-Forgues, Tian, & Siegler, 2015). Thus, fraction learning in school can cause children to lose interest in math (Jordan, Resnick, Rodrigues, Hansen, & Dyson, 2017). The dice in Parkopolis represent the familiar 1 to 6 on one die and visualizations of fractions divided into quarters (1/4, 2/4, 3/4, 4/4) on the other. Importantly, the game board spaces mimic the number line and are divided into fourths through tick marks and alongside each tick mark is the symbol for 1/4 or 1/2 so that children can recognize the similarity on the dice and game board. The number line design stems from the Integrative Theory of Numerical Development, which suggests that fractions and whole numbers are represented along the number line (Siegler & Lortie-Forgues, 2014). Several ancillary decisions supported fraction conversation on the board design. First, the board starts at space 0 to 1 rather than on space 1. Second, as children and adults progress through the game, they will have to add fractions such that a 3 and 1/2 roll might occur before a 2 and 3/4 roll.

Game cards. As children advance down the fraction number line, they land on spaces that direct them to game cards (Figure S2 in online supplementary materials), sparking research-based activities and challenges. Game cards (see Figure 4 e.g., cards) include a variety of content including numeracy, spatial, physical, and fluid reasoning activities. The numeracy and spatial tasks are known to predict later math outcomes (Sarama & Clements, 2002;

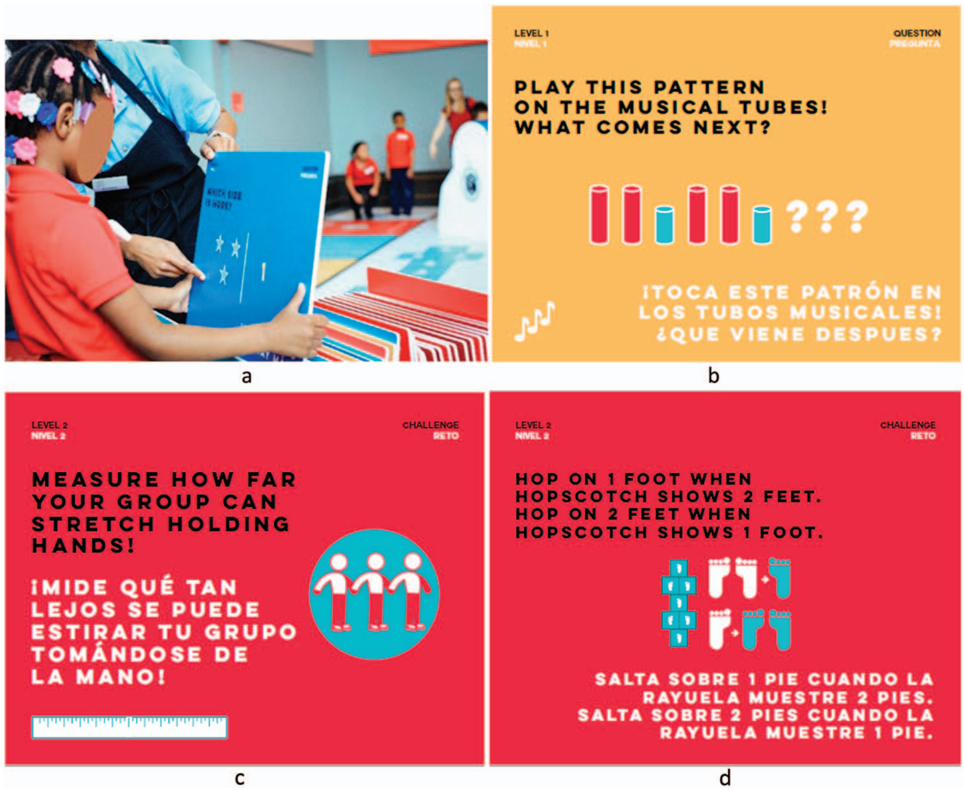

Figure 4. Designs for Parkopolis: (a) child reading math card, (b) card targeting patterns, (c) card targeting measurement, and (d) card targeting executive functioning. See the online article for the color version of this figure.

Geary, Bailey, & Hoard, 2009; Pruden & Levine, 2017). Similarly, the physical activity and gross motor skills have benefits for children's cognitive and health development (Verburgh, Königs, Scherder, & Oosterlaan, 2014; Jones, Hinkley, Okely, & Salmon, 2013). Fluid reasoning, which is the capacity to think logically and solve novel problems, is critical for scientific and computational thinking (Green et al., 2017; Wright, Matlen, Baym, Ferrer, & Bunge, 2008). Parkopolis cards also direct children to five stations within the game, pattern pipes, life size ruler, executive function hopscotch, planning dots, and the shape zone, where each target key STEM learning skills.

Pattern pipes. Music pipes were developed at different heights and colors that produce different tones when struck to allow children to mimic patterns requested by a card or played by a peer or caregiver (Figure S3 in online supplementary materials). Patterns are a key skill in math and science learning and are predictive of later math ability (Rittle-Johnson & Schneider, 2015; Geist, Geist, & Kuznik, 2012). These pattern games also exercise a core component of executive functioning (EF), short-term memory (STM), known to predict later school success (Blair, Raver, & Finegood, 2016; Diamond & Lee, 2011; Gathercole, Pickering, Knight, & Stegmann, 2004).

Life size ruler. Parkopolis features a giant ruler (Figure S4 in online supplementary materials), which combines gross motor skills with measurement, a key aspect of both math and science education (National Research Council, 2012; Szilagyi, Clements, & Sarama, 2013). Children can measure how far they can jump, how tall they are, or the difference in height between them and their peers. Game cards encourage children to count in multiples by jumping down the ruler number line by two's or three's, and exercise STM when their friend jumps on five numbers and they have to jump on the same numbers in the same order.

Executive functioning hopscotch. Reimagining the classic playground game (see Figure 5) by recreating it with stimuli patterns from the "Happy Sad Task", hopscotch is an executive function measure that captures cognitive flexibility and inhibition (Lagattuta, Sayfan, & Monsour, 2011). Matching the random pattern of footprints on the ground exercises children's cognitive flexibility, requiring them to quickly shift their attention (a core element of executive function) as they jump. Additionally, signage can challenge children to use two feet when the hopscotch shows one foot and one foot when it shows two, targeting their cognitive inhibition and flexibility (core executive function skills). Importantly, executive function skills may be malleable and predict later academic outcomes (Diamond & Lee, 2011; McClelland & Cameron, 2018; St Clair-Thompson & Gathercole, 2006).

Shape zone. This activity offers an array of typical and atypical shapes of different colors and sizes (Figure S5 in online supplementary materials), allowing children to learn early geometry, an important contemporaneous math skill that predicts to future math outcomes (Clements et al., 2004; Verdine, Lucca, Golinkoff, Hirsh-Pasek, & Newcombe, 2016). Similarly to exec-

Figure 5. Executive Functioning Hopscotch. See the online article for the color version of this figure.

utive function hopscotch, the shape zone targets cognitive flexibility when the game cards ask children to jump with their left foot on all of the squares and their right foot on all of the diamonds, and STM when their friend jumps on five shapes and they have to jump on the same five shapes in the same order.

Planning dots. The last element of Parkopolis is the planning dots (Figure S6 in online supplementary materials) — four circles of different colors scattered on the board that require children to develop and execute a plan as well as communicate effectively with others, both key approaches to learning skills (Bustamante, White, & Greenfield, 2017). Children are prompted by the game cards to run and touch the dots in a particular order, requiring them to plan their route. Alternatively, children may be asked to have a caregiver or peer close their eyes and lead them to the dots in a particular order using only their words, an exercise in communication.

Open-Ended Rule Design and Signage

We intentionally left the game open-ended with respect to the rules for playing it so that children could develop creative ways to move around the board with their caregivers and peers. This open-ended element of the game allows children to develop a tolerance for ambiguity, a key skill in computational thinking (Barr, Harrison, & Conery, 2011; Pérez, 2018). In addition, colorful signage around the room encourages caregivers to get involved in play, ask open-ended questions, use math and science language, and encourage persistence (see Figure 6).

Rocket Room Activities

The Rocket Room provided hands on opportunities for children and families. First, the room had two launching stations where children held a button to charge, and pressed a second button to launch, foam rockets with air cannons. The rockets were held in a large container in the middle of the room, and children were encouraged to assemble the foam rockets and then launch them through a series of large rotating rings hanging from the ceiling (see Figure 3). Second, the Rocket Room contained a space shuttle replica for dramatic play and historic toys with a space or robot theme. For example, there was a pilot station with a series of buttons and levers that replicated a control panel for a pilot. Third, there was a large transparent rocket with spiraling tracks lining the interior walls; children were able to pull a lever to release a ball and then watch it roll down the tracks all the way to the bottom of the rocket. The size and layout of the Rocket Room was identical to the room used for Parkopolis in an opposite corner of the museum.

Procedure

Observer training. Observers included eight postdoctoral, graduate, postbaccalaureate, and undergraduate research assistants. Each observer participated in comprehensive interrater reliability training sessions where they were trained to use discrete observation techniques. Following the training, observers conducted live double-coded observations on-site with the trainers until they reached 80% or higher interrater reliability. Once reliability was established, observers were permitted to code independently; 15% of all observations were doubled coded throughout the study to ensure continued interrater reliability. Observers were blind to study hypotheses, except for the postdoctoral fellows and graduate student who ran the trainings and were used primarily for double coding to ensure reliability. Observers also coded for age and gender. Age was examined at ±1 year, which was 75% consistent, and ±2 years, which was 88% consistent between raters. Gender was 85% consistent for children and 100% consistent for adults.

Observing caregiver–child interaction. Research assistants stood in the two exhibits and discretely observed families who entered the exhibit and stayed for at least 1 min. The amount of time each coder spent in each exhibit was counterbalanced such that coders spent a proportionally equivalent amount of time in each exhibit. Researchers recorded caregiver–child language and interaction in 5-min intervals, unless the families left before 5-min were up, and then stopped to complete the observational protocol (Figure S7). If families were still present after the researcher was finished completing the observational protocol, researchers resumed coding for an additional 5-min and repeated this procedure for up to 3 cycles.

The observational procedures and protocols were adapted from previous Playful Learning Landscapes studies (Hassinger-Das, Bustamante, Hirsh-Pasek, & Golinkoff, 2018; Ridge et al., 2015). Researchers tallied caregiver and child language, including whole number, fraction, spatial, reasoning, measurement, and pattern language, as well as predictions, observations, planning, and asking questions. Importantly, the observational coding was adapted to pull for the specific kinds of language targeted in Parkopolis — for example, fractions. For instance, definitions of the language categories from the coding manual see Table S2. To increase reliability, caregiver and child language tallies were recoded on a 5-point scale (*0 utterances* = 1, *1–5 utterances* = 2, *6–10 utterances* = 3, *11–15 utterances* = 4, and *16 + utterances* = 5); ratings + or – 1 on the 5-point scale were considered reliable. Reliability across the recoded language categories mentioned above was very high, ranging from $\alpha = .97$ to $\alpha = 1$.

Researchers also coded caregiver and child nonverbal engagement, such as physical activity (sedentary, moderate, vigorous), technology use (none, low, mid, high), and proportion of time spent engaged (low, moderate, high). For detailed descriptions of

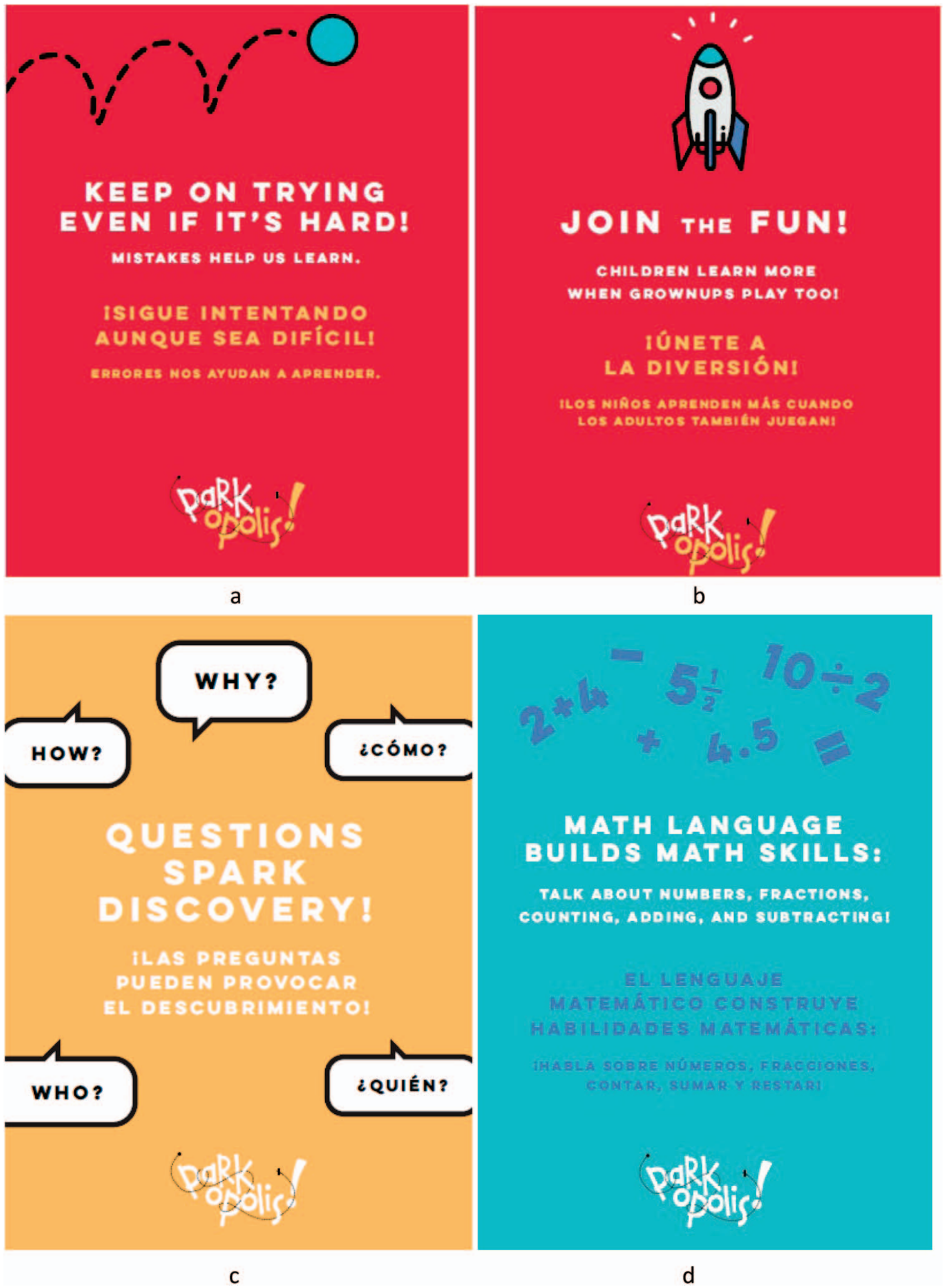

Figure 6. Signage in Parkopolis: (a) persistence sign, (b) caregiver involvement sign, (c) question asking sign, and (d) math language sign. See the online article for the color version of this figure.

the observational coding schemes, see Table S3. Caregiver–child interactions were also coded, including the number of turns in verbal interactions (0, 1–5, 6–10, 11–20, 20+), amount of interaction (low, moderate, high), caregiver communication style (mostly directive, neutral, follow's child's lead), and valence of interaction (very negative, negative, neutral, positive, very positive). If a caregiver interacted with multiple children, the coders counted all interactions and noted the number of children and their gender. For these variables, an exact match was required across coders for reliability; therefore, interrater reliability was more modest. Reliability in these categories were as follows: physical activity (adult, α = .81, child, α = .76), technology use (adult, α = .91, child, α = 1), proportion of engagement (adult, α = .73, child, α = .83), turns in verbal interactions (α = .75), amount of interaction (α = .65), caregiver communication style (α = .59), and valence of interaction (α = .66). Overall, research assistants demonstrated strong interrater reliability with an average of α = .93 across all categories.

Analysis Plan

To examine the effect of Parkopolis on caregiver–child language and interactions in comparison to the Rocket Room, a series of path models were run in Mplus Version 7.4 (Muthén & Muthén, 2017). To control for the nested nature of the data (observation cycles within families) standard errors were clustered at the family level using the "CLUSTER" command. This approach is comparable to hierarchical linear modeling, particularly in cases without level-2 predictors as is the case in the current study (McNeish, Stapleton, & Silverman, 2017). Parameter estimates were adjusted for missing data using full information maximum likelihood (FIML) estimation. FIML uses all available data for each case when estimating parameters (Mueller & Hancock, 2008).

The model was built based on predictor and criterion variables that would allow us to test all three hypotheses. To answer the first and second hypotheses, we examined the effect of Parkopolis on the caregiver's (H1) or the child's (H2) use of STEM language, engagement, physical activity, and use of technology. Thus, the model included 10 dependent indicators of STEM language, including whole numbers, fractions, spatial, measurement, reasoning, pattern, prediction, observation, planning language, and question asking; one indicator of caregiver and child engagement; one indicator of caregiver and child physical activity; and one indicator of caregiver and child technology use. The overall model accounted for time spent in the exhibit, mean age of children, and gender for measures used to answer H1 and H2. For the third hypothesis (H3), we examined the effect of child–caregiver interactions by including in our model four indicators of turns in verbal interactions, overall level of interaction, caregiver communication style, and valence of interactions. For H1 and H3, we also controlled for the number of caregivers (adult females and adult males) in addition to the controls used for H2.

To determine model fit, the Bentler comparative fit index (CFI) was examined, based on the criterion that values >0.95 were considered acceptable fit (Bentler, 1990). The standardized root mean square residual (SRMR) was examined, with values below 0.08 considered acceptable model fit (Hu & Bentler, 1999). Finally, the root mean square error of approximation (RMSEA) was also examined, with values below 0.06 considered adequate model fit (Browne & Cudeck, 1992). We did not focus on chi-square as a metric of fit, given that it can provide unreliable estimates with large sample sizes (Kline, 2011).

Results

Families spent an average of 3.9 min playing Parkopolis (SD = 3.5) versus 4.1 min in the Rocket Room (SD = 1.2) a nonsignificant difference, t = .91, p = .36. Observations in both exhibits ranged from 1 to 15 min. Given that children playing Parkopolis were estimated to be slightly older (M = 5.40 years, SD = 2.57 vs. M = 5.07 years, SD = 2.36; t = 1.77, p = .08) and more likely to be female (54% vs. 44%; t = 2.52, p = .01) than children in the Rocket Room condition, gender, age, and time spent in the exhibit were included as covariates in all analyses. For complete descriptive statistics, see Table 1. Complete results of the model are presented in Tables 5, 6, and 7. The final model met criteria for all three previously mentioned indices (RMSEA = .03; CFI = .99; SRMR = .02), thus this model was retained as having adequate model fit. Results as organized by study hypotheses below:

> *Hypothesis 1:* Caregivers will demonstrate increased STEM language, engagement, and physical activity and decreased technology use in Parkopolis, compared to the Rocket Room.

Notably, adults in Parkopolis used significantly more whole number language (β = 0.83, $p < .01$), fraction language (β = 0.60, $p < .01$), reasoning language (β = 0.24, $p < .01$), and pattern language (β = 0.62, $p < .01$), asked more questions (β = 0.40, $p < .01$), engaged in more physical activity (β = 0.65, $p < .01$), and showed a higher proportion of engagement (β = 0.39, $p < .01$), compared to the Rocket Room, controlling for time in exhibit, number of caregivers, and gender of caregivers. Adults in Parkopolis also spent significantly less time on their cell phones (β = −0.38, $p < .01$), made fewer observations (β = −0.22, p = .02), and used less planning language (β = −0.49, $p < .01$), compared to the Rocket Room, controlling for the same covariates mentioned above (see Table 2 for summary and covariate statistics).

> *Hypothesis 2:* Children will demonstrate increased STEM language, engagement, and physical activity, and decreased technology use in Parkopolis, compared to the Rocket Room.

Children playing Parkopolis used significantly more whole number language (β = 0.93, $p < .01$), fraction language (β = 0.39, $p < .01$), reasoning language (β = 0.18, $p < .01$), measurement language (β = 0.18, p = .02), and pattern language (β = 0.54, $p < .01$) and engaged in more physical activity (β = 0.40, $p < .01$) compared to the Rocket Room, controlling for time in the exhibit, age, and gender. Children playing Parkopolis, however, made significantly fewer predictions (β = −0.27, p = .01) and observations of their surroundings (β = −0.25, $p < .01$) and used less planning language (β = −0.36, $p < .01$) compared to the Rocket Room, controlling for the same covariates mentioned above (see Table 3).

> *Hypothesis 3:* Caregivers and children will exhibit increased levels of interaction (i.e. conversational turns, amount of interaction, valence of interaction, caregiver communication style), in Parkopolis, compared to the Rocket Room.

Caregivers and children playing Parkopolis took significantly more conversational turns (β = 0.345, $p < .01$) and demonstrated higher levels of interaction (β = 0.38, $p < .01$) compared to the Rocket Room, controlling for time in exhibit, age and gender of children, number of caregivers, and gender of caregivers (see Table 4).

Discussion

This study examined the effects of a life-sized board game that was designed using principles from the science of learning to promote playful STEM learning opportunities. We hypothesized this newly designed game would relate to caregiver and child language and interaction, physical activity, and technology use. Compared to a control STEM focused exhibit at the same children's museum, caregivers in Parkopolis demonstrated greater STEM language, engagement, and physical activity, asked more

Table 1
Descriptive Statistics for Parkopolis and Rocket Room Including Mean Recoded Language Scores, Mean Raw Language Scores, and the Percentage of Families Who Used a Category of Language or Behavior in Parkopolis, in the Rocket Room, and the Difference Between Them

Variable	Min	Max	Parkop. *M* recoded (Std.Dev)	Parkop. *M* raw (Std.Dev)	Rock. Rm recoded *M* (Std.Dev)	Rock. Rm *M* raw (Std.Dev)	% present in Parkop.	% present in Rock. Rm	% Diff.
Adults per family	1	5		1.65 (.78)		1.64 (.75)			
Children per family	1	11		2.03 (1.12)		1.97 (1.01)			
Child age in years	1	14		5.40 (2.57)		5.07 (2.36)			
Time in exhibit (minutes)	1	5		3.51 (3.5)		4.10 (1.2)			
Adult whole num lang	1	5	2.67 (1.43)	6.21 (6.45)	1.60 (.79)	1.74 (3.19)	74.76%	45.83%	28.92%
Adult fraction lang	1	5	1.32 (.60)	.86 (1.88)	1.05 (.32)	.07 (.67)	26.21%	2.92%	23.30%
Adult spatial lang	1	5	1.63 (.83)	1.92 (3.20)	1.64 (.74)	1.72 (2.68)	45.63%	52.08%	−6.45%
Adult reasoning lang	1	2	1.25 (.44)	.38 (.79)	1.16 (.43)	.20 (.57)	25.00%	15.00%	10.00%
Adult measurement lang	1	3	1.13 (.35)	.28 (.88)	1.16 (.42)	.22 (63)	12.86%	14.58%	−1.72%
Adult pattern lang	1	5	1.23 (.46)	.38 (.90)	1.02 (.27)	.01 (.07)	22.33%	.83%	21.50%
Adult prediction lang	1	5	1.05 (.27)	.05 (.26)	1.11 (.38)	.13 (.44)	3.88%	9.58%	−5.70%
Adult observation lang	1	5	1.48 (.55)	1.00 (1.60)	1.62 (.63)	1.39 (1.97)	46.36%	55.83%	−9.47%
Adult planning lang	1	3	1.30 (.47)	.51 (1.05)	1.54 (.58)	1.00 (1.41)	29.37%	51.25%	−21.88%
Adult questions	1	5	1.96 (.76)	2.80 (3.18)	1.68 (.69)	1.61 (2.48)	75.00%	58.33%	16.67%
Adult physical activity	0	2	1.12 (.59)		.74 (.49)		22.57% (Vigorous)	2.50% (Vigorous)	20.07%
Adult technology use	0	3	.36 (.71)		.68 (.95)		23.54%	40.00%	−16.46%
Adult engagement	1	3	2.36 (.72)		2.06 (.69)		47.57% (High)	25.83% (High)	21.74%
Child whole num lang	1	5	2.72 (1.54)	6.83 (7.53)	1.41 (.72)	1.06 (2.47)	70.63%	31.67%	38.96%
Child fraction lang	1	2	1.14 (.36)	.25 (.77)	1.03 (.29)	.03 (.20)	14.08%	2.08%	11.99%
Child spatial lang	1	3	1.27 (.48)	.53 (1.20)	1.25 (.51)	.47 (1.12)	25.00%	23.33%	1.67%
Child reasoning lang	1	2	1.09 (.29)	.12 (.41)	1.05 (.31)	.03 (.20)	9.22%	3.33%	5.89%
Child measurement lang	1	2	1.07 (.26)	.11 (.48)	1.05 (.31)	.04 (.25)	7.04%	3.33%	3.71%
Child pattern lang	1	2	1.22 (.44)	.36 (.96)	1.03 (.29)	.02 (.13)	21.36%	2.08%	19.28%
Child prediction lang	1	2	1.01 (.11)	.02 (.16)	1.08 (.35)	.07 (.32)	1.21%	6.25%	−5.04%
Child observation lang	1	3	1.31 (.48)	.54 (1.08)	1.45 (.60)	1.20 (1.86)	30.83%	41.25%	−10.42%
Child planning lang	1	2	1.17 (.38)	.21 (.52)	1.32 (.52)	.50 (.93)	16.99%	30.42%	−13.43%
Child questions	1	3	1.51 (.54)	1.06 (1.52)	1.47 (.56)	.85 (1.24)	49.51%	45.00%	4.51%
Child physical activity	0	2	1.72 (.48)		1.50 (.53)		69.66% (Vigorous)	50.42% (Vigorous)	19.24%
Child technology use	0	1	.02 (.18)		.04 (.27)		.97%	2.50%	−1.53%
Child engagement	1	3	2.71 (.51)		2.74 (.45)		69.66% (High)	70.42% (High)	−.76%
Conversational turns	0	4	1.49 (.89)		1.17 (.58)		40.53% (6+ Turns)	22.08% (6+ Turns)	18.45%
Level of interaction	1	3	2.25 (.72)		1.98 (.69)		41.02% (High)	22.50% (High)	18.52%
Caregiver comm. style	0	3	2.11 (.83)		1.99 (.96)		37.38% (Child Led)	37.08% (Child Led)	.30%
Valence of interactions	0	4	2.59 (.69)		2.61 (.78)		44.66% (Positive)	45.83% (Positive)	−2.41%

Note. Parkop. = Parkopolis; Rock. Rm = Rocket Room; Num = Number; Lang = Language.

questions, and spent less time on their mobile devices. Children playing Parkopolis also used more STEM language and engaged in more vigorous physical activity than children in the comparison exhibit. Caregiver–child groups engaged in dialog with more conversational turns and demonstrated increased levels of interaction in Parkopolis versus the comparison exhibit. These results suggest that Parkopolis relates more strongly than the Rocket Room to the types of caregiver–child dialog and interactions that research suggests promote learning and development (Levine et al., 2010; Gunderson et al., 2011; Pruden et al., 2011) in a playful and physically active context. For example, Levine et al. (2010) found that increased "number talk" between 14 and 30 month-olds predicted 46-month-olds' knowledge of the cardinal meaning of number words after controlling for SES and other measures of child–parent interactions. This study suggests how environments can organically generate the kinds of conversations and interactions that previous research has found to be predictive of later outcomes. These findings are in line with previous PLL studies showing that installations grounded in the science of learning can be effective vehicles for providing playful learning opportunities to children and their families (Grob, Schlesinger, Pace, Golinkoff, & Hirsh-Pasek, 2017; Hassinger-Das et al., 2019; Ridge et al., 2015). This study advances the PLL initiative in several important ways.

Parkopolis is the first PLL installation to present a coordinated game comprised of a set of research-based activities that explicitly

Table 2
Adult Language, Physical Activity, Technology Use, and Engagement Results From Hierarchical Regression Analyses

Parameter estimates	Unstandardized	*SE*	Standardized (β)	*p*-value
Parkopolis → adult whole number lang.	1.094	.098	.825	<.001
Time in exhibit → adult whole number lang.	.000	.001	.000	.355
# Female caregivers → adult whole number lang.	.253	.078	.191	.001
# Male caregivers → adult whole number lang.	.070	.087	.053	.421
Parkopolis → adult fraction lang.	.301	.036	.597	<.001
Time in exhibit → adult fraction lang.	.000	.000	.000	.094
# Female caregivers → adult fraction lang.	.025	.031	.049	.420
# Male caregivers → adult fraction lang.	.028	.035	.056	.423
Parkopolis → adult spatial lang.	−.025	.074	−.032	.734
Time in exhibit → adult spatial lang.	.000	.000	.000	.405
# Female caregivers→ adult spatial lang.	.064	.056	.082	.254
# Male caregivers → adult spatial lang.	−.012	.054	−.015	.827
Parkopolis → adult reasoning lang.	.099	.074	.241	.004
Time in exhibit → adult reasoning lang.	.000	.000	.000	.667
# Female caregivers → adult reasoning lang.	.015	.056	.036	.566
# Male caregivers → adult reasoning lang.	−.012	.054	−.077	.285
Parkopolis → adult measurement lang.	−.015	.031	−.043	.634
Time in exhibit → adult measurement lang.	.000	.000	.000	.948
# Female caregivers → adult measurement lang.	.037	.022	.108	.082
# Male caregivers → adult measurement lang.	.003	.029	.008	.927
Parkopolis → adult pattern lang.	.246	.027	.622	<.001
Time in exhibit → adult pattern lang.	.000	.000	.000	.320
# Female caregivers → adult pattern lang.	.041	.022	.104	.038
# Male caregivers → adult pattern lang.	−.023	.023	−.058	.307
Parkopolis → adult prediction lang.	−.053	.025	−.181	.066
Time in exhibit → adult prediction lang.	.000	.000	.000	.260
# Female caregivers → adult prediction lang.	.007	.015	.025	.616
# Male caregivers → adult prediction lang.	.002	.023	.005	.946
Parkopolis → adult observation lang.	−.126	.053	−.217	.018
Time in exhibit → adult observation lang.	.000	.000	.000	.240
# Female caregivers → adult observation lang.	.006	.033	.010	.862
# Male caregivers → adult observation lang.	−.052	.045	−.090	.236
Parkopolis → adult planning lang.	−.247	.045	−.490	<.001
Time in exhibit → adult planning lang.	.000	.000	.000	.131
# Female caregivers → adult planning lang.	−.017	.033	−.034	.599
# Male caregivers → adult planning lang.	−.015	.037	−.030	.689
Parkopolis → adult question lang.	.299	.067	.404	<.001
Time in exhibit → adult question lang.	.000	.000	.000	.256
# Female caregivers → adult question lang.	.181	.056	.244	<.001
# Male caregivers → adult question lang.	.044	.058	.059	.447
Parkopolis → adult physical activity	.373	.049	.645	<.001
Time in exhibit → adult physical activity	.000	.000	.001	.032
# Female caregivers → adult physical activity	.038	.037	.065	.301
# Male caregivers → adult physical activity	.036	.044	.062	.416
Parkopolis → adult technology use	−.297	.078	−.378	<.001
Time in exhibit → adult technology use	.000	.000	.000	.272
# Female caregivers → adult technology use	−.041	.048	−.052	.329
# Male caregivers → adult technology use	−.099	.061	−.126	.098
Parkopolis → adult proportion of engagement	.282	.066	.390	<.001
Time in exhibit → adult proportion of engagement	.000	.000	.000	.639
# Female caregivers → adult prop. of engagement	−.072	.045	−.099	.107
# Male caregivers → adult prop. of engagement	−.027	.052	−.037	.605

target STEM skills — traditionally taught in school — in a playful and informal setting. Findings suggest that families are willing to engage in a game that targets STEM learning goals during their leisure time and that both caregivers and children may use more relevant language and interact with an overall positive valence. Standardized effect sizes in the current study were quite large for this type of educational intervention (ranging from .16 to .93). Parkopolis was related to a greater percentage of STEM language use across a variety of categories. Specifically, engaging with Parkopolis compared to the Rocket Room predicted more use of whole number, fraction, and pattern language for children and adults. The relationship between STEM language use and Parkopolis versus the control condition suggests potentially powerful implications for promoting STEM language between young children and their families — a predictor of later STEM skills (Levine et al., 2010; Verdine et al., 2017).

These large effects on caregiver–child language and interaction are even more impressive when considering the use of a STEM, activity-based control condition. Having a highly engaging and hands-on STEM exhibit as the comparison site might explain why

Table 3
Child Language, Physical Activity, Technology Use, and Engagement Results From Hierarchical Regression Analyses

Parameter estimates	Unstandardized	*SE*	Standardized (β)	*p*-value
Parkopolis → child whole number lang.	1.366	.105	.932	<.001
Time in exhibit → child whole number lang.	.001	.001	.000	.257
Mean age → child whole number lang.	.114	.027	.078	.000
# of boys → child whole number lang.	.173	.065	.118	.007
# of girls → child whole number lang.	.128	.065	.087	.048
Parkopolis → child fraction lang.	.116	.022	.399	<.001
Time in exhibit → child fraction lang.	.000	.000	.000	.279
Mean age → child fraction lang.	.017	.006	.057	.007
# of boys → child fraction lang.	.018	.016	.062	.260
# of girls → child fraction lang.	.021	.014	.073	.137
Parkopolis → child spatial lang.	.005	.043	.010	.912
Time in exhibit → child spatial lang.	.000	.000	.000	.322
Mean age → child spatial lang.	.024	.011	.050	.029
# of boys → child spatial lang.	.051	.027	.107	.053
# of girls → child spatial lang.	.090	.025	.188	.000
Parkopolis → child reasoning lang.	.045	.018	.178	.008
Time in exhibit → child reasoning lang.	.000	.000	.000	.307
Mean age → child reasoning lang.	.013	.007	.052	.046
# of boys → child reasoning lang.	.003	.014	.014	.800
# of girls → child reasoning lang.	.031	.014	.125	.021
Parkopolis → child measurement lang.	.041	.019	.184	.021
Time in exhibit → child measurement lang.	.000	.000	.000	.945
Mean age → child measurement lang.	.000	.003	.000	.989
# of boys → child measurement lang.	.018	.014	.083	.191
# of girls → child measurement lang.	.020	.011	.092	.067
Parkopolis → child pattern lang.	.185	.025	.538	<.001
Time in exhibit → child pattern lang.	.000	.000	.000	.221
Mean age → child pattern lang.	.026	.008	.077	<.001
# of boys → child pattern lang.	−.002	.015	−.006	.900
# of girls → child pattern lang.	.024	.016	.071	.126
Parkopolis → child prediction lang.	−.047	.018	−.270	<.001
Time in exhibit → child prediction lang.	.000	.000	.000	.407
Mean age→ child prediction lang.	.000	.002	.001	.967
# of boys →child prediction lang.	.004	.012	.022	.748
# of girls → child prediction lang.	−.002	.008	−.009	.852
Parkopolis → child observation lang.	−.126	.047	−.245	.007
Time in exhibit → child observation lang.	.000	.000	.000	.325
Mean age→ child observation lang.	.007	.010	.013	.517
# of boys → child observation lang.	.075	.028	.145	.007
# of girls → child observation lang.	.070	.025	.136	.004
Parkopolis → child planning lang.	−.152	.038	−.361	<.001
Time in exhibit → child planning lang.	.000	.000	.000	.529
Mean age → child planning lang.	.025	.009	.059	.006
# of boys → child planning lang.	.048	.026	.115	.059
# of girls → child planning lang.	.077	.023	.183	.001
Parkopolis → child question lang.	.042	.048	.080	.379
Time in exhibit → child question lang.	.000	.000	.000	.804
Mean age → child question lang.	.038	.013	.071	.003
# of boys → child question lang.	.033	.031	.062	.283
# of girls → child question lang.	.073	.025	.138	.004
Parkopolis → child physical activity	.209	.048	.403	<.001
Time in exhibit → child physical activity	.000	.000	.000	.274
Mean age → child physical activity	.022	.011	.042	.041
# of boys → child physical activity	.131	.028	.253	.000
# of girls → child physical activity	.107	.026	.205	.000
Parkopolis → child technology use	−.019	.013	−.147	.050
Time in exhibit → child technology use	.000	.000	.000	.124
Mean age → child technology use	−.003	.004	−.026	.277
# of boys → child technology use	−.005	.007	−.035	.469
# of girls → child technology use	.004	.005	.033	.362
Parkopolis → child proportion of engagement	−.033	.043	−.069	.434
Time in exhibit → child proportion of engagement	.000	.000	.001	.170
Mean age → child proportion of engagement	.019	.010	.039	.049
# of boys → child proportion of engagement	.046	.026	.096	.077
# of girls → child proportion of engagement	.059	.023	.123	.008

Table 4
Adult and Child Interaction Results From Hierarchical Regression Analyses

Parameter estimates	Unstandardized	*SE*	Standardized (β)	*p*-value
Parkopolis → turns in verbal interaction	.273	.070	.345	<.001
Time in exhibit → turns in verbal interaction	.000	.000	.000	.324
# Female caregivers → turns in verbal interaction	.111	.043	.140	.009
# Male caregivers → turns in verbal interaction	.075	.064	.095	.237
Mean age → turns in verbal interaction	.069	.018	.087	.000
# of boys → turns in verbal interaction	.027	.045	.034	.546
# of girls → turns in verbal interaction	−.004	.045	−.006	.922
Parkopolis → overall level of interaction	.271	.065	.376	<.001
Time in exhibit → overall level of interaction	.000	.000	.000	.421
# Female caregivers → overall level of interaction	−.041	.044	−.056	.358
# Male caregivers → overall level of interaction	.035	.050	.048	.484
Mean age → overall level of interaction	.001	.012	.001	.931
# of boys → overall level of interaction	.012	.029	.016	.677
# of girls → overall level of interaction	.024	.024	.034	.315
Parkopolis → caregiver communication style	.069	.089	.078	.436
Time in exhibit → caregiver communication style	.000	.000	.000	.920
# Female caregivers → caregiver comm. style	−.123	.063	−.138	.052
# Male caregivers → caregiver comm. style	−.018	.067	−.020	.787
Mean age → caregiver communication style	.022	.021	.024	.294
# of boys → caregiver communication style	−.124	.057	−.139	.028
# of girls caregiver → communication style	−.005	.051	−.006	.921
Parkopolis → valence of interaction	−.018	.068	−.025	.788
Time in exhibit → valence of interaction	.000	.000	.000	.349
# Female caregivers → valence of interaction	.092	.054	.128	.087
# Male caregivers → valence of interaction	−.019	.052	.026	.722
Mean age → valence of interaction	−.033	.020	−.046	.095
# of boys → valence of interaction	−.052	.044	−.072	.244
# of girls → valence of interaction	−.034	.039	−.048	.375

caregivers and children each made significantly more observations and used more planning language in the Rocket Room compared to Parkopolis. The Rocket Room provided a very exciting activity where children launched rockets 20–30 feet in the air, and such an activity provides many opportunities for caregivers and children to plan how they will use the rocket launcher and observe what happens when they launch the rockets. Indeed, the Rocket Room — a professionally designed children's museum STEM exhibit — demonstrated the ability to elicit STEM language and interactions and may have shown additional value if the observations had focused on STEM concepts that are more aligned with the exhibit such as force and direction. Similarly, Parkopolis elicited multiple specific types of STEM language and interactions it was designed to target, and there are areas with further potential where future iterations of Parkopolis and PLLs in general could be improved to engage interactions that elicit more observations and planning.

In addition, some of our STEM outcomes showed no differences when compared to the Rocket Room, which may suggest further areas for improvement. Parkopolis is a unique platform that invites many ways to interact with children across a broad age range, and all of the designs were directly derived by research in the science of learning to increase exposure to STEM language and interactions that foster learning. Overall, it is highly encouraging that Parkopolis engendered significantly more STEM talk and interaction compared to a different STEM oriented children's museum exhibit. Future iterations of Parkopolis in outdoor public spaces may provide even greater impacts, as most playgrounds are unlikely to offer such exciting STEM learning opportunities.

Another strength of this study was the examination of outcomes beyond STEM content language. In an environment where attention to screens disrupts social interaction and learning opportunities (Reed, Hirsh-Pasek, & Golinkoff, 2017), and studies have found that technoference — technology driven interferences — are related to child internalizing and externalizing behaviors (Mc Daniel & Radesky, 2018), caregivers in Parkopolis spent less time on their mobile devices and more time actively engaged in the game with their child compared to the control condition. Indeed, fewer adults engaged with their cell phones in Parkopolis compared to the Rocket Room, and more caregiver-child dyads were rated as demonstrating a high level of interaction in Parkopolis versus the Rocket Room. We speculate that the complexity of playing a coordinated game may have driven this result since many of the children were preliterate. Though children were intrigued by Parkopolis, they needed scaffolding from their caregiver to engage with the game. In contrast, once children figured out how to assemble and launch the rockets in the Rocket Room, caregivers let children play independently. The reduced level of mobile phone activity may not be uniquely related to STEM activities specifically, as this finding may be achievable with other engaging non-STEM activities. Results suggest that the Parkopolis provides a STEM focused experience that is engaging enough for families to spend time interacting with each other more than with their mobile devices. Given the value in rich conversation and parent–child interaction, this is a strength of the Parkopolis design. Even older, literate, children typically engaged with caregivers to develop rules for the game and encouraged their caregivers to play, as turn-taking and competing against an opponent are hallmarks of most board games. Yet, we caution readers that the coding for amount of interaction demonstrated low reliability ($\alpha = .65$); thus these advantages should be interpreted with caution.

Physical activity is another important study outcome. In addition to the running, jumping, skipping, and hopping built into nearly all elements of Parkopolis, there are a set of activity cards that target exercise and gross motor skills such as cards that prompt children and caregivers to "Do 5 squats!", "Do 10 jumping jacks!", or "Stand on 1 foot for 15 seconds!" Physical activity and gross motor skills are predictive of later health outcomes and have demonstrated cognitive benefits (Verburgh et al., 2014; Jones et al., 2013). We also note that several children and caregivers played Parkopolis in wheelchairs. In order to serve all children in public spaces we made an intentional effort for installations to be handicap accessible.

Limitations and Future Directions

Though this study had notable strengths mentioned above, it is not without limitations. First, in order to maintain high ecological validity and not disrupt the natural flow of participants engaging with the exhibits as well as reduce reactivity, the study was observational, without random assignment. Thus, we caution readers to not make causal inferences based on our findings. Future studies are underway to experimentally examine the effects of Parkopolis on children's in-school STEM outcomes.

Further, this study took place at a children's museum and not in a public space like other PLL installations. This means participating families may be more likely to engage and interact with their children because they are in a children's museum, which could invite a mindset of play and learning. Thus, Parkopolis must be tested in an urban public setting before generalizing these results to other city parks or playgrounds. Additionally, the museum is full of exciting exhibits and stimulating experiences, thus families are often mindful of the amount of time they spend in any single exhibit because they want to see everything the museum has to offer. This, along with the young age of child visitors (approximately 2 to 7 years of age on average), likely explains the relatively short amount of time families spent in Parkopolis and the Rocket Room exhibits (approximately 4 min on average per family). Again, future research should test Parkopolis in an urban public space that has fewer competing activities to investigate if setting affects the quality or duration of caregivers and children's interactions during the game. Our observations also suggest that 25% of participants that visited Parkopolis stayed long enough to be observed for a second and third cycle, compared to 13% in the Rocket Room; however, our covariate for Time in Exhibit was not a significant predictor in the models and did not change the observed pattern of results.

Another limitation of this study is that observers, while blind to hypotheses, were not blind to condition. It was not a realistic possibility to withhold the information that our lab developed Parkopolis from the observers or that families were in the Rocket Room versus a board game activity. However, the strong interrater reliability suggests that observers were recording consistent, observable behavior. It should be noted that three codes did not demonstrate that same high level of reliability as the others — amount of interaction ($\alpha = .65$), caregiver communication style ($\alpha = .59$), and valence of interaction ($\alpha = .66$) — thus, these categories should be interpreted with additional caution. Future research should explore alternative means of data collection. For example, recording devices (e.g., the LENA audio transcribing software) and video recording caregiver–child interactions for later coding by a blind observer are two ways that technology could mitigate some of the aforementioned concerns. These devices can interfere with the natural interactions of the families and could cause both caregivers and children to behave differently while they play. In this study we opted for a more naturalistic approach to increase the ecological validity of the study. Additionally, our museum partners did not permit the use of audio or video recording to protect the privacy of their patrons. However, recording techniques could yield novel insights and should be considered for future studies.

Although this study was able to capture caregiver–child language and interactions, which have been demonstrated to predict later STEM outcomes (Berkowitz et al., 2015; Pruden et al., 2011; Uttal & Cohen, 2012), we cannot draw conclusions about child learning in Parkopolis because we did not directly measure learning outcomes. Future iterations of Parkopolis should measure STEM learning outcomes before and after children and families engage with Parkopolis to test potential impacts on children's learning. It may be the case that additional scaffolding for caregivers or guided learning would be necessary to help children have an experience that boosts their STEM knowledge in a meaningful way (Fisher et al., 2013). Or there may be a minimum amount of time or number of visits to Parkopolis before children experience STEM learning (Anderson et al., 2000).

Several other procedural limitations should be noted. Observers estimated age and gender of participants. Estimates were reliable across observers, which suggests that they are likely close in the majority of cases. Additionally, some families may have been observed in both the Parkopolis and Rocket Room conditions, as museum patrons often visit multiple exhibits. We do not anticipate that this would bias our estimates in any systematic or meaningful way.

Future iterations of Parkopolis should systematically examine whether Parkopolis provides age appropriate activities for children at different developmental levels. One might imagine that the open-ended nature and variety of the game or the presence of fractions might be intimidating or uninviting to younger children. However, anecdotal accounts of our observers suggest that caregivers of younger children used terms that may be precursors to formal fraction terms, like "part" or a "piece of the whole." In fact, one of the activities that younger children were the most excited to do was spin the dice and have their caregivers call out the number (or fraction of the number) they rolled, and parents seemed to provide developmentally appropriate terminology. Indeed, children who were too young to engage in the full game took turns playing patterns on the music pipes with their caregiver, matched the feet on the hopscotch game, jumped on the ruler and engaged in measurement, or jumped in the shape zone and identified shapes. While it appears that Parkopolis invited the youngest learners to participate and maintained enough rigor to challenge older learners, future studies should examine this systematically by comparing quantifiable verbalizations to explore the appeal and effectiveness of Parkopolis for different aged learners. This becomes increasingly important as we attempt to extend Parkopolis into public spaces where young people of all ages will want to play.

Conclusion

Findings from this study provide a proof of concept that we can design broad appeal activities that can augment what children learn in school. Parkopolis serves as an evidence-based platform for promoting STEM language, caregiver-child interaction, and physical activity. If the encouraging results from this study can be replicated in an urban public space, Parkopolis could have serious implications for eliciting STEM language and interaction between caregivers and children, potentially promoting informal STEM learning in the 80% of time children spend outside of school. Considering global urbanization trends, Parkopolis has the potential to reach large numbers of children and families via densely populated urban settings. Parkopolis — along with the other Playful Learning Landscapes installations — may provide cities with scalable and sustainable infrastructure that is backed by rigorous research to enrich public spaces where children and families already go with engaging playful STEM learning opportunities.

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