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An Observational Investigation of How Exhibit Environment and Design Intersect to Influence Parent–Child Engagement

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ABSTRACT
This naturalistic, observational study examined how specific design elements in two play-centered science center exhibits influence child and parent engagement. We observed the level of engagement, pretend play, and sharing among 57 3- to 9-year-olds ($M = 5.67$ years) and their parents at either an indoor, technology-based exhibit or an outdoor, nature-based exhibit. Overall, exhibit elements that were interactive or allowed for free play engaged children the most and fostered the most pretend play and sharing, regardless of indoor or outdoor environment. Directed play elements were associated with increased levels of parent involvement with their children at the exhibit, particularly outdoors. These novel results demonstrate how exhibit-level factors influence parent and children's engagement in informal contexts. Implications for children's autonomy in guiding their own informal learning experiences and recommendations for museum exhibit space design are discussed.

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Exhibit design; interactive learning; museums; parent–child relations; play and playthings; visitor engagement

Introduction

In general, it is thought that children's learning occurs through their exploration of the world (Piaget, 1970). For example, children learn about causal structures through the exploration and manipulation of objects in their environment; a finding that has been demonstrated in both the laboratory (e.g., Gopnik et al., 2001; Schulz & Bonawitz, 2007) and in museum settings (Callanan et al., 2020). Informal learning environments have become central to the examination of children's learning through exploration. Children not only learn about causal structures in these settings, but also conceptual knowledge (e.g., engineering concepts; Benjamin et al., 2010) and facts about specific entities (e.g., human biology; Falk, 1993; Native American history, Jant et al., 2014; animals, Marble et al., 2021). In addition, informal learning experiences strengthen the skills needed for future learning, including persistence, critical thinking, creativity,

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and collaboration (Bustamante et al., 2019; Golinkoff & Hirsh-Pasek, 2016). Summarizing decades of research on the Science of Learning, Hirsh-Pasek et al. (2015) posited that effective learning occurs in naturalistic learning settings when children are actively engaged with the content and scaffolded by social interaction.

A substantial body of work also suggests that the social-interactive features of play are critical to children's cognitive and social development (Singer et al., 2006; Vygotsky, 1962). Although recent research in museums and science centers has advanced efforts to examine the parent–child interactions that promote informal learning (Callanan et al., 2017; Haden, 2010; Leinhardt et al., 2002), it remains unclear how transactions between child, parent, and context contribute to exploration in play-centered exhibits (see Falk & Dierking, 2000). Indeed, play-centered exhibits are designed specifically to encourage child engagement, as well as parent involvement, in a variety of cognitively challenging behaviors, ideas, and experiences beyond those encountered in daily life (Henderson & Atencio, 2007; Jant et al., 2014).

The current study investigated how the physical context of informal learning settings (e.g., exhibit design) influences child engagement and parent involvement. Note that specific learning outcomes were not measured in the current study, but instead the focus is on engagement as a criterion for learning (Hirsh-Pasek et al., 2015). Specifically, the study objectives were to examine: (1) the extent to which children's frequency and duration of exhibit interactions are influenced by the exhibit design (2) how two specific child engagement behaviors (i.e., pretend play and sharing) differ according to exhibit design, and (3) whether the type of parent involvement varies across exhibit designs. We examined these engagement and involvement behaviors across two environments (i.e., indoor and outdoor) to address whether the science center staff's design goal for both environments to promote child engagement and parent–child interactions was met.

Child engagement and exhibit design

Child engagement is important for learning in informal education environments (see Callanan et al., 2020; Hirsh-Pasek et al., 2015, for reviews). Time spent at exhibits and the frequency with which individuals interact with exhibit features are two of the most common metrics of engagement and have been linked to later learning (Sanford, 2010). For example, the time spent at exhibits and observable behaviors indicative of engagement (e.g., pushing buttons, looking at a graphic display) predicted adolescents' performance on an exhibit content-specific test (Falk, 1993). In addition, time spent and frequency of interaction with an exhibit both predicted the level of family learning with 5- to 10-year-olds and their parents (e.g., Borun et al., 1996). Although time and frequency are individually related to learning, the use of multiple metrics provides the fullest picture of child engagement (Sanford, 2010).

Little is known about how specific exhibit design features promote visit duration and frequency. It is important to understand which exhibit designs provide children with optimal opportunities for engagement as science centers and children's museums seek to design exhibits that leverage engagement to effectively encourage transfer of knowledge from museums to other settings. Specifically, research that differentiates between *exhibit forms, functions*, and *play structures,* and in different *environments* (i.e., indoors versus outdoors) can provide valuable information on the facets of exhibit design that promote better engagement (Bustamante et al., 2019; Degotardi et al., 2019; Fisher et al., 2013). These exhibit design categories were specifically used by science center staff in the design of the two play-centered exhibits observed in the current study.

Exhibit form

A central aim of the current study was to examine the unique contributions of multiple exhibit forms to children's overall engagement. Exhibit form constitutes the physical configuration, material characteristics, and sensory properties of a specific exhibit element (Bustamante et al., 2019). In the current study, we focused on the following exhibit forms: *technology*, *nature*, *replicas*, *activity stations*, and *playground equipment* (see Table 1). To date, no current research has compared how these exhibit forms differentially relate to child engagement, but each form has the potential to facilitate engagement in unique ways.

For instance, technological exhibit elements are highly appealing and promote learning through frequent interaction with contingent feedback on performance and progress (Druin, 2009; McKnight & Cassidy, 2010). Nature exhibits in zoos and aquariums provide children rare and valuable opportunities for close encounters and even direct interactions with a range of wildlife that promote learning about animals (Ganea et al., 2011; LoBue et al., 2013). Replicas of real-world objects and structures may facilitate children's engagement by providing opportunities to take part in rich pretend play scenarios and explore aspects of the world that are otherwise inaccessible to them (Jant et al., 2014; Lillard et al., 2013). Activity stations demonstrate scientific or other applied concepts and are intended to engage children in scientific learning and causal reasoning (Willard et al., 2019). Playground exhibits often are designed to elicit children's active participation and physical development (Bagot et al., 2015; Pellegrini & Smith, 1998).

Exhibit function

Exhibit function refers to the primary operation, objective, or focus of each exhibit element (see Table 1). In the naturalistic learning contexts offered by museums and science centers, children have the opportunity to engage with a variety of exhibit functions designed to encourage hands-on, active learning, which facilitates retention of educational content (Falk & Dierking, 2000). Although children's immediate impression and interest may be based on the physical properties of the exhibit (i.e., form), the functional elements may be more likely to determine the breadth and depth of engagement. Specifically, *interactivity*- defined as an interchange of actions or ideas in response to previous exchanges with objects or others- has been found to enhance children's attentional interest, engagement, and learning outcomes (Ganea et al., 2011; Markopoulos et al., 2008). Within the museum context, Degotardi et al. (2019) found that interactive exhibits, ones that included hands-on activities and audio-visual or technical elements with contingent responses, elicited higher levels of child engagement and conversations between parents and children. Accordingly, exhibit interactivity is considered essential to children's museum learning experiences (e.g., Andre et al., 2017).

Table 1. Exhibit form, function, and play structure classifications.

Classification	Description
A. Exhibit form	**Code assigned based on focal or central features of the exhibit area.**
1. Technology	Computer, tablet, or electronic features like switches, lights, and recorded sounds.
2. Nature	Animals, plants, or their habitats.
3. Replicas	Manufactured objects or structures that simulate real places and things.
4. Activity stations	Functional learning stations that simulate real structures/machines and activities.
5. Playground	Recreational playsets such as swings, see-saws, or slides.
B. Exhibit function	**Code assigned based on primary play function, features, or focus.**
1. Instructional	Conveying factual or scientific knowledge/understanding.
2. Interactive	Actively engaging with objects, organisms, or structures (without changing/ constructing).
3. Constructive	Working with available materials to construct or create something.
4. Active	Physical or motor activity.
C. Exhibit play structure	**Code assigned based on format of initiation and implementation of play.**
1. Free play	Child voluntarily chooses what, how, and with whom to play. Lack of rules or clearly identified structure allows child autonomy freely to plan and engage in chosen activity.
2. Guided play	Child follows flexible activity rules, procedure, or guidelines, which allow child some autonomy to make decisions. Adults may guide activity through modeling, suggestions, or explanations.
3. Directed play	Child learns through direct adult instruction or discussion.

Instructional and *constructive* exhibit functions offer additional, more explicit learning opportunities. Instructional functions are meant to convey specific knowledge about a topic and constructive functions provide children with opportunities to learn about engineering and physics concepts or causal structures (e.g., Benjamin et al., 2010; Callanan et al., 2020). Because these exhibits are not inherently interactive, in that they do not include contingent responses to children's actions, they may not foster engagement to the same degree as other functions. However, exhibit form may interact with functional elements to promote engagement. For example, instructional exhibits that include live animals may be more engaging to children than other instructional exhibit forms (e.g., dioramas, signs).

Play structure

Educational play is distinctive in that children are relatively free to direct themselves regarding what and with whom they learn (Falk & Dierking, 2000). Exhibits designed to promote play typically imbue one of three types of play structures: *free play*, *guided play*, or *directed play*. Free play refers to self-directed activities that are voluntary, engaging, flexible (i.e., no defined extrinsic goals), and enjoyable (Smith & Pellegrini, 2013). Free play has traditionally been recognized as optimal for promoting child engagement and social interaction with peers, but scaffolded play may translate to deeper learning (Dean & Kuhn, 2007; Legare et al., 2017). Guided play facilitates children's flexible, interest-driven experiences by encouraging their natural curiosity, active engagement, and "sense-making" processes (Fisher et al., 2013; Weisberg et al., 2016). Finally, directed play refers to structured, instruction-based activities with clear learning objectives (Zosh et al., 2018). In a meta-analysis, free play consistently emerged as the play structure that promoted the lowest level of learning compared to both guided or directed forms of structure, and direct instruction was related to the highest level of learning (Alfieri et al., 2011). Given that direct instruction is most effective for formal learning but least engaging to children (Legare et al., 2017), we examined the extent to which direct instruction was evident in play-centered exhibits and how it compared to the other types of play structures.

Indoor and outdoor play environments

Exhibit environment (i.e., indoor versus outdoor) provides a broader context in which exhibit forms, functions, and play structures may affect children's level of engagement and parent interaction. The combination of indoor and outdoor environments at many museums and science centers offers a unique opportunity to examine a rich array of children's play behaviors as they relate to the physical design of exhibits (Falk & Dierking, 2000). Due to the distinct properties of indoor and outdoor environments (Clements, 2004), some exhibit forms, functions, and play structures may be more prevalent in one environment over the other

Children's play indoors increasingly centers around technology (Rideout, 2013; Zimmermann et al., 2017), which is immediately and intuitively engaging to children (Druin, 2009; Markopoulos et al., 2008; McKnight & Cassidy, 2010). Technological play enhances children's spatial skills, although hands-on indoor activities such as puzzles, block play, and construction may be more valuable still in this respect (Eisen & Lillard, 2016; Uttal et al., 2009). Further, technology offers only limited opportunities for creativity and direct social engagement (Levin & Rosenquest, 2001), and interactions with parents may focus on the technology itself rather than the intended educational content (Degotardi et al., 2019). Given these potential limitations, there may be educational advantages to outdoor play, which tends to focus more on the natural elements of the environment rather than technological elements (Henderson & Atencio, 2007). Childhood play in natural environments is inherently exploratory, which helps children develop navigation skills, autonomy, and appreciation for nature (Bixler et al., 2002; Chipeniuk, 1995; Strife & Downey, 2009). Outdoor play encourages active, physical movement that can enhance children's categorization and recall in perspective taking and spatial imagery tasks (Clements, 2004; Pellegrini & Smith, 1998).

Children's specific engagement behaviors

The second primary goal of the current study was to examine how exhibit design facilitates two specific engagement behaviors: pretend play and sharing. Pretend play and sharing are salient during early and middle childhood and are linked to positive developmental outcomes (Dunfield et al., 2011; Eisenberg et al., 1999; Sutherland & Friedman, 2012). Exhibits for child visitors are designed to promote imaginative and interactive play to harness children's intrinsic desire to play (Mayfield, 2005). The play-centered exhibits in the current study were designed to encourage children's play and social interaction, broadly construed, and the replicas were specifically intended to promote pretend play. By measuring these observable behaviors, we can gain insight into whether children are using the exhibits as they were intended (i.e., another metric of engagement; Sanford, 2010).

Because pretend play is considered the cornerstone of cognitive development and symbolic thinking in early childhood (Lillard et al., 2013), the examination of how exhibit design influences children's pretend play provides additional insight into how exhibit design may promote multiple cognitive abilities indirectly. Pretend play refers to child behaviors that exhibit role playing, symbolically transforming objects by assigning new meanings and uses (e.g., changing a science center map into a food truck menu), utilize imaginative themes and narratives, and engage in role transformations like becoming a pirate or farmer, either individually or with others (Lillard et al., 2013; Sutherland & Friedman, 2012). Pretend play is considered essential to healthy child development and engenders positive cognitive abilities such as creativity, mental state understanding, and reasoning abilities (see Lillard et al., 2013, for review). Children as young as 2 years of age are also able to acquire general knowledge, such as facts about animals, through pretend play (Sutherland & Friedman, 2012, 2013). Exhibits that provide items that elicit pretend play and physical manipulation harness children's intrinsic motivation to learn and establish the foundation to catalyze more complex and abstract pretend play (Leinhardt et al., 2002; Ryan & Deci, 2000).

Similarly, unsolicited sharing may be embedded into the play context in informal learning environments. The same exhibit items that promote pretend play also provide children with opportunities to share with others in their family group or with unfamiliar peers. Sharing is an important aspect of prosocial development; children who engage in unsolicited sharing during early and middle childhood exhibit more sympathy, perspective taking, and helping behaviors as young adults (Eisenberg et al., 1999). By age 3, children understand they are expected to share with others and judge that resources should be distributed fairly (Paulus et al., 2013). Nonetheless, young children are notoriously poor at the equitable sharing of desired possessions until ages 7–8 (Smith et al., 2013). Because sharing is difficult for young children, they benefit from the opportunities to practice sharing in their everyday environments (Barragan & Dweck, 2014). Therefore, the role of informal learning environments in facilitating sharing is an important but understudied issue that requires further investigation.

Exhibit design may differentially facilitate both pretend play and sharing. For example, interactive replicas likely foster children's engagement in pretend play, because many of these exhibits encourage children to take on specific roles (e.g., farmer, pirate) and include many different items that can be used during pretend play narratives (e.g., fake food, steering wheel, buttons that make sounds). The presence of these items in replica exhibits may foster sharing as children interact with others with similar interests in interactive replica elements. Exhibits that have a free play structure may similarly facilitate pretend play and sharing. Free play exhibits have fewer structured activities and less specific ways to interact with the exhibit, leaving children free to construct pretend play narratives.

Parent involvement in children's exhibit exploration

Finally, we considered how exhibit design influences parent involvement in children's exploration of play-centered exhibits. Children's learning in museums and science centers is enhanced by active adult guidance, which has led to a transition to more family-oriented museum experiences (Andre et al., 2017; Benjamin et al., 2010). Indeed, children engage more with museum exhibits when doing so with caregivers than when exploring exhibits alone (Crowley et al., 2001). Without developmentally appropriate parental guidance to help scaffold learning and assist children with challenging social behaviors such as sharing, children may fail to extract key concepts when engaging in free play, even with enriched materials (Fender & Crowley, 2007; Uttal et al., 2009). For instance, children's free-choice physical interactions, such as pressing buttons or operating devices, fail to result in long-term learning (Bamberger & Tal, 2007). In contrast, conversational instruction coupled with hands-on activities result in children's learning and information retention immediately after the exhibit and again after two weeks (Benjamin et al., 2010; Jant et al., 2014). In addition, parent–child interactions are considered among the most important factors related to the quantity, complexity, quality, and diversity of imaginary play exhibited by children (e.g., Van Schijndel et al., 2010). Together, these findings indicate that caregiver involvement in the museum learning process may increase the likelihood that information is retained and applied beyond the museum.

The level of necessary parent involvement depends on various factors, including the learning goals of the situation and children's skills and abilities. Appropriate scaffolding occurs when parents are sensitive to when their children need direct assistance and when they should allow their children to explore and discover on their own (Wood et al., 1976). Medina and Sobel (2020) demonstrated how children with more directive parents learned parts of the causal structure better than children with parents who guided the interaction but did not provide direct instruction. However, children with guiding parents explored the causal system for a longer time than children with directive parents, suggesting that a more hands-off approach fostered deeper engagement with the apparatus. Similarly, parents who are intrusive or overly directive when engaged in pretend play with their children may limit the complexity of imaginary play by restricting children's ability to explore independently (Youngblade & Dunn, 1995). Research into children's interactive museum learning should attend to whether the child or parent initiates and leads collaborative play (Sobel & Kushnir, 2006).

Like children's play behaviors, certain exhibit designs may foster different levels of parent involvement. Children may require more parental directing when interacting with exhibit elements that have specific directions or methods (i.e., directed or guided play structures). In addition, parents may need to help children navigate exhibits that have unfamiliar technology or require children to construct a certain product. Finally, parents might be more involved in scaffolding children's learning at exhibit elements with nature forms and instructive functions.

The current study

We measured the duration and frequency of play at an indoor, technology-based exhibit (SciPlay Bay) and an outdoor, nature-based exhibit (Jeansboro Junction) to examine the extent to which child engagement is influenced by the exhibit form, function, and play structure in indoor versus outdoor environments. The two exhibits were designed with the intent to provide children and parents with two unique play-centered experiences within the broader science center context. Although these two exhibits are comprised of different activities along the technology-nature spectrum, the design goal of both areas was to provide exhibits that promote child engagement and parent–child interactions. Beyond examining the differences between different forms, functions, and play structures, the science center's overarching purpose for commissioning the current study was to examine whether both the indoor and outdoor exhibits equally met these goals and whether the exhibit design elements function in similar ways within each environment. To this end, we predicted that overall levels of engagement and parent and child behaviors would not differ by exhibit environment. We did not have any specific predictions regarding interactions between exhibit environment and the other design categories. On one hand, it is possible that the exhibit forms, functions, and play structures may differentially facilitate engagement and behavior in two different environments. On the other hand, the exhibit design categories may function in the same manner independent of environment.

Regarding the exhibit design categories, we predicted that children would engage more frequently and longer with technology indoors and live animals outdoors than other exhibit forms. We also expected that interactive functions and free play structured exhibit elements would be more engaging to children overall. We also examined differences in children's pretend play and sharing behaviors and parent involvement according to these exhibit characteristics. We predicted that children would engage in more pretend play and sharing in replica forms, interactive functions, and free play structured exhibit elements. In turn, we expected parent directing would be highest at exhibit elements with technology and nature forms, instructive and constructive functions, and guided and directed play structures.

Method

Participants

Fifty-seven 3- to 9-year-old children (*M* = 5.67 years, *SD* = 22.78 months, 30 females) and their caregivers were observed interacting at one of two children's play-centered exhibits in a science center located in a mid-sized city in Southeastern USA. Caregiver-identified demographics indicated that participating children were 75.4% White, 8.8% African American, 3.5% biracial/multiracial, and 4% Latinx and had a median annual household income of $60-$90,000 (range = $15,000–$365,000). Families with 3- to 9-year-olds and at least one legal guardian in the group were invited to participate. All children in participating groups received a small toy at the end of the observation session.

Materials

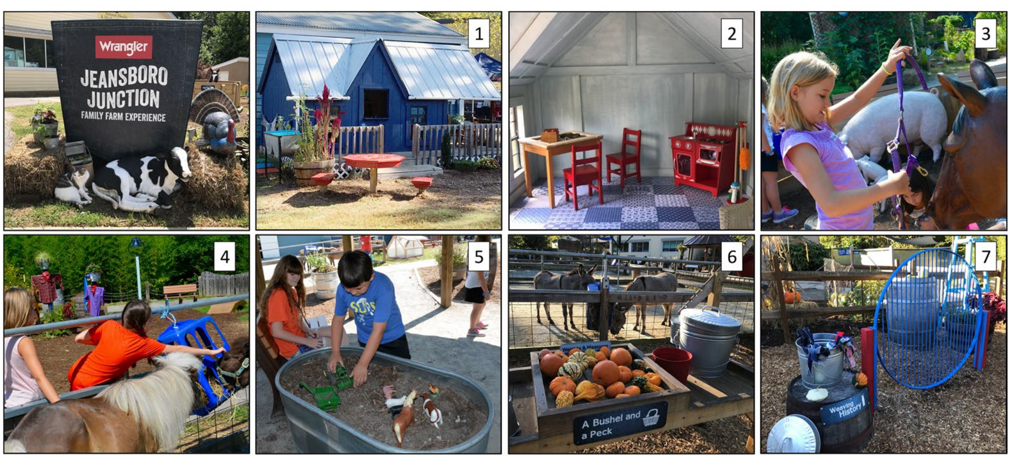
Family interactions were observed either in SciPlay Bay – an indoor, beach-themed exhibit that features nautical replicas (e.g., a submarine and pirate ship) and technological activities (e.g., hand-activated marionette projection, fish light sensors, and button activated lights and sounds) – or in Jeansboro Junction – an outdoor, farm-themed exhibit that includes live animals (e.g., goats, horses, and coatis) and agricultural replicas (e.g., farmhouse). SciPlay Bay consists of two conjoined rooms that amount to 7,296 square feet. Jeansboro Junction covers one acre (i.e., 43,560 square feet). Both exhibits were designed to adhere to the 60:40 exhibit to public space density. Observed exhibit elements are depicted in Figure 1 (see Appendix A for a full list and details on exhibit elements in SciPlay Bay and Jeansboro Junction, respectively).

Observation sessions were audio recorded using the Azden 310/330 series UHF wireless system, which included two microphone packs with a single dual channel wireless receiver. The Azden receiver was connected to the H1 Zoom Handy Recorder (purchased separately) to provide a single, clear recording of both child and guardian and to allow one of the researchers wearing standard headphones to listen to parent–child speech live during an observation session. The caregiver's microphone was clipped

(a) SciPlay Bay (Indoor) Exhibit Elements

Note. 1 = Pirate Ship, 2 = Submarine, 3 = Food Truck, 4 = Octopus Drums, 5 = Marionette, 6 =Flying Colors Wall, 7 = Palm Fort

(b) Jeansboro Junction (Outdoor) Exhibit Elements



Note. 1, 2 = Farmhouse, 3 = Fair Fun, 4 = Petting Zoo, 5 = Mulch Pit, 6 =Weigh Station, 7 = Weaving Station

Figure 1. Exhibit elements in SciPlay Bay and Jeansboro Junction.

to their lapel, and their microphone pack either was kept in a pocket, in a personal bag, or was clipped to their clothing waistband. The target child's microphone pack was stored in a child-friendly miniature backpack worn for the duration of observation with the microphone clipped to the shoulder strap.

Procedure

Participants were recruited as they entered either the SciPlay Bay or Jeansboro Junction exhibits at the Greensboro Science Center. After obtaining caregivers' consent and permission, as well as assent from children 7 or older, both the child and adult participants were equipped with microphone sets. Families were told to spend as much time at the exhibit ($M = 15.54$ minutes, range = $5.55 - 52.72$ minutes) and to interact with as many exhibit elements as they desired ($M = 6.64$, range = $3 - 12$). A pair of trained researchers observed the dyad from an inconspicuous distance. One researcher timed the length of the visit and recorded the frequency and duration that the dyad engaged with each exhibit element. The second researcher listened to dyad interactions through earbuds and recorded observed child engagement behaviors and parent involvement at each exhibit element. Researcher observations at the science center typically were conducted 1–2 times weekly, usually but not always on weekends. Researcher observations also took place at different periods of the day (e.g., morning, afternoon) throughout the testing period.

Measures

Observational coding

The observational coding system was based on prior research (e.g., Andre et al., 2017; Van Schijndel et al., 2010) and refined through extensive pilot observations at both science center exhibits. Exhibit engagement was scored for both frequency and duration. *Engagement frequency* was calculated based on the total number of child interactions with each exhibit element[1], while *engagement duration* measured the total time in minutes that the target child spent at each exhibit element.

Children's specific engagement behaviors were recorded for instances of pretend play and sharing. *Pretend play* was operationalized as role-taking (enacting roles through imitative action or verbalization, such as adopting an exaggerated tone of voice or making animal noises), narrative construction (developing play scripts to maintain joint action and dialogue), pretense actions (establishing shared meaning through a common frame of reference regarding the play context and direction), symbolic or novel use of objects (using an object for or as something other than its intended function), and verbal substitution of actions (e.g., "I'm riding a unicorn!"). Other-oriented *sharing* was coded when children relinquished possession of an object or resource they controlled, liked, and wanted in direct response to another's perceived desire or need for the resource (Dunfield et al., 2011). Every exhibit element was assigned a score of 1 each time the target child demonstrated pretend play or sharing (separately) and a score of 0 if the behavior did not occur while engaging with the exhibit element.

Similarly, *parent involvement* was observed for uninvolved, child-guided, and parent-directed interactions with the target child. *Uninvolved* parents did not engage with the target child within an exhibit element in any way and were not actively paying attention to the target child while the child engaged with the exhibit element. *Child-guided* involvement signified that parents actively monitored, responded to, and encouraged the target child's play within an exhibit element but did not control or direct the play. In turn, *parent-directed* interactions were coded when parents initiated and lead the interaction with an exhibit element. For example, parents frequently read their children signage or directed their attention at the live animal exhibits outdoors or instructed children on how to activate technological features in the indoor exhibit. Parents received an involvement code for each level of involvement (0 = absent, 1 = present) for all exhibit elements that they visited and could receive multiple "present" codes if their level of involvement changed over the course of the visit with the exhibit element.

Exhibit classification coding

Three trained researchers familiar with both exhibits reliably coded each exhibit element according to Exhibit Form, Function, and Play Structure (see Table 1). To ensure validity, staff members at the science center who run the exhibits also were asked to code the exhibit elements, and strong reliability was reached across raters. No single reliability estimate was below 80% agreement (kappas > .75). *Exhibit Form* was classified as technology, nature, replica, activity station, or playground equipment based on the focal features of the exhibit elements. *Exhibit Function* was assigned based on the primary purpose or focus of the exhibit elements and included instructional, interactive, constructive, and active. Finally, *Play Structure* was coded as free, guided, or directed play based on the initiation, implementation, and format of play.

Some exhibit elements contained multiple features that were classified as different forms, functions, or play structures. When this occurred, the features were considered separate exhibit elements for the frequency analyses and the parent and child behavior analyses (e.g., the pirate ship was composed of three subordinate elements: run around ship, ship props, and fish light sensors). Some exhibit elements received multiple codes from each design category but were assigned the single code that was endorsed at the highest rate among the coders (e.g., the submarine in SciPlay Bay is both a replica and has technology elements, but coders coded the submarine as a replica at the highest rate). See Appendix A for a list of exhibit elements, engagement descriptive statistics, and classifications for SciPlay Bay and Jeansboro Junction.

Results

Data preparation

Outliers

The duration data were checked for outliers. Any data points that were 1.5 interquartile ranges above the third quartile were considered extreme cases. The values of these cases were replaced with the maximum value of the 1.5 interquartile range. Seven percent of data points were identified as outliers across both exhibits, all exhibit elements, and all participants.

Missing data

Participants who did not visit certain exhibit elements did not receive child behavior or parenting involvement codes. Missing data were imputed by taking the average of participants' individual averages for each behavior for the exhibits they did visit and the average for each exhibit design category based on the participants who did visit the exhibit element (computed separately for each exhibit, SciPlay Bay and Jeansboro Junction). For example, if Jeansboro Junction participants visited nature, replica, and playground exhibit forms but did not visit any activity stations, their pretend play mean was first calculated based on their rate of pretend play at nature, replica, and playground forms. Next, the activity station pretend play mean was calculated for participants who did visit activity stations in Jeansboro Junction. Finally, the participants' pretend play averages for activity stations were calculated by taking their individual pretend play mean and the activity station pretend play mean. Thirty percent of the data was imputed across all design categories and all child and parent behaviors. The overall pattern of the data remained the same following the imputation (e.g., pretend play remained the highest at replicas and lowest at technology/nature exhibit forms).

Preliminary analyses

Preliminary analyses were conducted to determine whether child age or gender were associated with the dependent measures. A series of 2 Exhibit Environment (indoors, outdoors) X 2 Child Age (younger or older than 5 years) X 2 Child Gender (boy, girl) analyses of variance (ANOVAs) were computed separately for each dependent measure (engagement, children's specific engagement behaviors, and parent involvement). Child engagement, measured by both frequency and duration, did not differ by child age or gender and there were no significant interactions between the demographic variables and exhibit environment, all $ps > .05$. Pretend play and sharing did not differ by child age or gender and there were no significant interactions between the demographic variables and exhibit environment, all $ps > .05$.

Uninvolved parenting and parent-directed involvement did not differ by child age or gender and there were no significant interactions between the demographic variables and exhibit environment, all $ps > .05$. Child-guided parent involvement, however, was more common for younger children compared to older children, ($Ms = .80, .67$), $F(1, 49) = 4.48$, $p = .04$, $\eta_p^2 = .08$, but there was no interaction between child age and exhibit environment for child-guided involvement, $F(1, 49) = 0.46$, $p = .50$, $\eta_p^2 = .01$.

Primary analyses

Consistent with study aims, analyses were conducted in multiple steps. First, we investigated exhibit engagement based on the frequency and duration of child interactions with each exhibit element. Then, we examined differences in children's specific engagement behaviors (pretend play, sharing) and parent involvement (uninvolved, child-guided, or parent-directed). All associations were tested using mixed ANOVAs,

Table 2. Child engagement behaviors by exhibit environment, form, function, and play structure ANOVAs.

Design category	Main effect *F*-value/ η_p^2	Exhibit design element *mean (SE)*				Interaction *F*-value/ η_p^2
Form	*df* (3, 165)	Technology/ nature	Replica	Activity station	Playground	X environment
Frequency	4.97** .08	.57[a] (.04)	.54[a] (.06)	.29[b] (.05)	.64[a] (.12)	1.70 .03
Duration	2.79* .05	2.43[a] (.18)	2.63[a] (.22)	1.95[b] (.13)	2.33[ab] (.22)	6.22*** .10
Indoors		2.68[a] (.26)	2.99[a] (.33)	1.83[b] (.19)	1.74[b] (.32)	
Outdoors		2.18[a] (.25)	2.28[a] (.31)	2.07[a] (.19)	2.93[a] (.30)	
Function	*df* (3, 165)	Instructional	Interactive	Constructive	Active	X environment
Frequency	4.73** .10	.32[a] (.05)	.59[b] (.04)	.31[a] (.07)	.62[b] (.12)	2.18 .04
Duration	10.79*** .16	2.07[a] (.15)	3.19[b] (.21)	2.08[a] (.13)	2.22[a] (.22)	25.13*** .31
Indoors		3.29[a] (.22)	2.97[a] (.30)	2.14[b] (.18)	1.51[c] (.31)	
Outdoors		0.86[a] (.21)	3.40[b] (.28)	2.02[c] (.17)	2.93[b] (.30)	
Play structure	*df* (2, 110)	Free play	Guided play	Directed play		X environment
Frequency	3.33* .06	.55[a] (.06)	.38[b] (.04)	.40[ab] (.05)		14.17*** .21
Indoors		.61[a] (.09)	.52[a] (.06)	.19[b] (.07)		
Outdoors		.49[a] (.08)	.26[b] (.06)	.62[a] (.07)		
Duration	3.62* .06	3.03[a] (.26)	2.27[b] (.21)	2.56[ab] (.17)		7.76*** .12
Indoors		2.60[a] (.38)	2.59[a] (.30)	3.29[a] (.25)		
Outdoors		3.46[a] (.36)	1.95[b] (.28)	1.84[b] (.24)		

Note. Row means that share a common superscript do not differ significantly.
*$p < .05$,.
**$p < .01$,.
***$p < .001$.

with 2 Exhibit Environment (indoors, outdoors) as the between-subjects factor and either X 4 Exhibit Form (technology/nature[2], replica, activity station, playground), X 4 Exhibit Function (instructional, interactive, constructive, active), or X 3 Exhibit Play Structure (free, guided, directed) as the within-subject factor in separate analyses. Results were considered significant at $\alpha = .05$. Posthoc pairwise comparisons were conducted as part of each analysis and the Bonferonni-Holm correction was applied to correct for multiple comparisons. All inferential statistics for exhibit form, function, and play structure are presented in the tables; additional statistics will be presented in text.

Child engagement

The first set of analyses examined the frequency and duration of child engagement according to Exhibit Environment, Form, Function, and Play Structure. Results are presented in Table 2 and Figure 2.

Environment. There were no significant main effects of exhibit environment for either frequency or duration respectively, $Fs(1, 55) = 1.55, 0.08$, $ps = .22, .79$, $\eta_p^2s = .03, .00$.

Form. Children engaged the most frequently with technology/nature ($M = .57$), replica ($M = .54$), and playground ($M = .64$) forms compared to activity stations ($M = .29$). Similarly, children spent the most time at technology ($M = 2.68$) and replicas ($M = 2.99$) forms compared to activity stations ($M = 1.83$) and playgrounds ($M = 1.74$) indoors, but played equally long with all four forms outside, ($M_{nature} = 2.18$, $M_{replica} = 2.28$, $M_{station} = 2.07$, $M_{playground} = 2.93$).

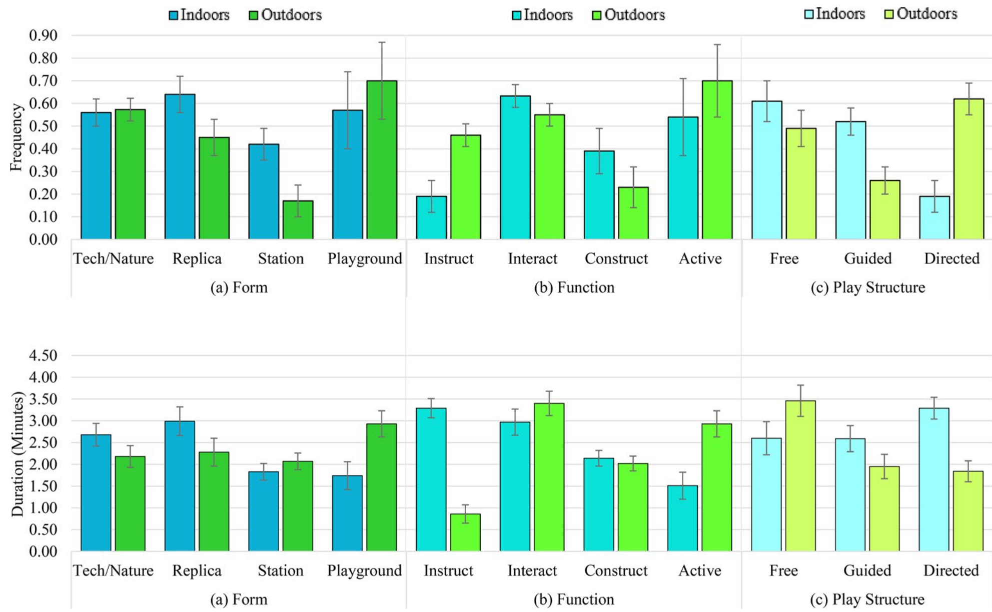


Figure 2. Child engagement frequency and duration by exhibit environment, form, function, and play structure.

Note: Tech/Nature = Technology Indoors and Nature Outdoors, Station = Activity Station. Error bars show standard errors.

Function. Children engaged most frequently with interactive (M = .59) and active (M = .62) functions and least frequently with instructional (M = .32) and constructive (M = .31) functions. Similarly, children spent the most time with interactive (M = 3.40) and active functions (M = 2.93) outdoors, and interactive (M = 2.97) and instructive (M = 3.29) functions indoors. Children spent the least time with active functions indoors (M = 1.51) and instructional functions outdoors (M = 0.86).

Play structure. Children engaged most frequently with free (M = .61) and guided (M = .52) play structures compared to directed (M = .19) play structures indoors and directed (M = .62) and free (M = .49) play structures compared to guided (M = .26) play structures outdoors. Conversely, children spent equal amounts of time at directed (M = 3.29) play structures compared to free (M = 2.60) and guided (M = 2.59) play structures indoors and spent the least amount of time at directed (M = 1.84) play structures compared to free (M = 3.46) play structures outdoors.

Interim summary: child engagement. Across exhibits, children engaged equally frequently with technology/nature, replica, and playground forms, and interactive and active functions. Indoors, children engaged most frequently with free and guided play structures while outdoors, children engaged most frequently with free and directed play structures. The duration results mostly reflected similar patterns as the frequency data except for a few notable departures, particularly with indoor and outdoor environments. Even though children engaged with playground forms frequently in both environments, they spent little time at playground forms indoors compared to outdoors. Similarly, although instructional and directed play exhibit elements were visited infrequently indoors, children spent more time at these exhibit elements indoors compared to outdoors.

Table 3. Child engagement behaviors by exhibit environment, form, function, and play structure ANOVAs.

Design category	Main effect F-value/ η_p^2	Exhibit design element *mean (SE)*				Interaction F-value/ η_p^2
Form	*df* (3, 165)	Technology/ nature	Replica	Activity station	Playground	X environment
Pretend play	17.09*** .24	.05[a] (.02)	.32[c] (.05)	.10[a] (.03)	.20[b] (.03)	7.40*** .11
Indoors		.10[a] (.03)	.27[b] (.07)	.14[ab] (.03)	.07[a] (.06)	
Outdoors		.01[a] (.03)	.37[b] (.07)	.06[a] (.03)	.32[b] (.05)	
Sharing	2.64 .05	.09[a] (.03)	.18[a] (.04)	.12[a] (.03)	.09[a] (.02)	4.75** .08
Indoors		.17[a] (.04)	.16[a] (.05)	.13[ab] (.04)	.03[b] (.04)	
Outdoors		.01 (.04)[a]	.20[b] (.05)	.11[b] (.04)	.14[b] (.03)	
Function	*df* (3, 165)	Instructional	Interactive	Constructive	Active	X environment
Pretend play	19.32*** .26	.01[a] (.01)	.18[b] (.03)	.08[c] (.02)	.25[d] (.04)	2.89* .05
Indoors		.00[a] (.01)	.18[b] (.05)	.09[ab] (.03)	.17[b] (.06)	
Outdoors		.01[a] (.01)	.17[b] (.05)	.07[c] (.03)	.32[d] (.05)	
Sharing	10.62*** .14	.00[a] (.00)	.17[b] (.04)	.15[bc] (.03)	.08[c] (.02)	3.06* .05
Indoors		.00[a] (.00)	.20[b] (.05)	.16[b] (.04)	.01[a] (.04)	
Outdoors		.00[a] (.00)	.14[b] (.05)	.14[b] (.04)	.14[b] (.03)	
Play structure	*df* (2, 110)	Free play	Guided play	Directed play		X environment
Pretend play	23.33*** .30	.28[a] (.04)	.13[b] (.03)	.04[c] (.01)		2.90 .05
Sharing	17.86*** .14	.20[a] (.04)	.08[b] (.02)	.01[c] (.01)		0.26 .02

Note. Row means that share a common superscript do not differ significantly.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Children's specific engagement behaviors

The second set of analyses assessed whether children's pretend play and sharing varied according to Exhibit Environment, Form, Function, and Play Structure (see Table 3, Figure 3).

Environment. There were no significant main effects of exhibit environment for either pretend play or sharing respectively, $Fs(1, 55) = 1.68, 0.001$, $ps = .20, .98$, η_p^2s = .03, .00.

Form. Across both environments, pretend play was highest at replica ($M = .32$) compared to technology/nature ($M = .05$) and activity station ($M = .10$) forms. Pretend play was observed at an equally high rate at playground forms outdoors ($M = .32$) but was observed lowest at playground forms indoors ($M = .07$). Sharing was lowest at nature forms outdoors ($M = .01$) but highest at technology forms indoors ($M = .17$). Sharing was equally high at replica ($M = .18$) and activity station ($M = .12$) forms in both environments and at playground forms outdoors ($M = .14$).

Function. Across both environments, pretend play and sharing were the least common at exhibit elements with instructional functions ($Ms = .01, .00$), and pretend play was also least common at constructive functions ($M = .08$). Pretend play was highest at interactive ($M = .18$) and active ($M = .25$) functions at both exhibits, and particularly high at active functions outdoors ($M_{indoors} = .17$, $M_{outdoors} = .32$). Sharing was highest at interactive ($M = .17$) and constructive ($M = .15$) functions in both environments, as well as at active functions outdoors ($M = .14$).

Play structure. Across both environments, children demonstrated more pretend play and sharing at free play ($Ms = .28, .20$) than guided ($Ms = .13, .08$) and directed ($Ms = .04, .01$) play structured exhibit elements.

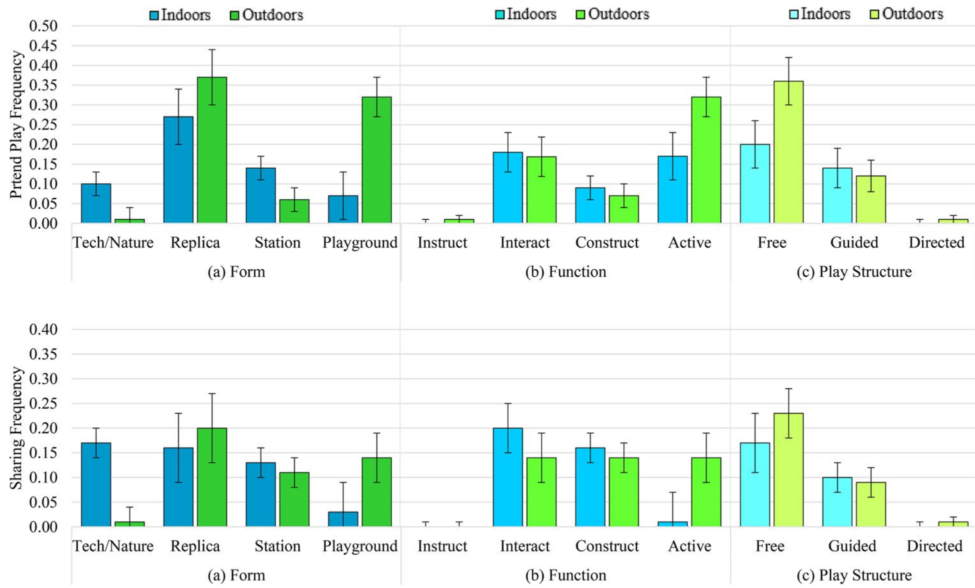


Figure 3. Child pretend play and sharing by exhibit environment form, function, and play structure.

Note: Tech/Nature = Technology Indoors and Nature Outdoors, Station = Activity Station. Error bars show standard errors.

Interim summary: children's specific engagement behaviors. Across both exhibit environments, pretend play and sharing were observed the most frequently at replicas and elements with free play structures and least frequently at instructional, guided play structure, and directed play structure exhibit elements. Sharing was also high at activity stations and constructive functions. Although pretend play and sharing did not differ by environment, these behaviors were facilitated by different forms and functions within each environment. Pretend play and sharing were observed at higher rates at playground and active elements outdoors, while sharing was observed at higher rates at technology exhibits.

Parent involvement

The final set of analyses assessed whether parent involvement in their children's play differed according to Exhibit Environment, Form, Function, and Play Structure. Results are shown in Table 4 and Figure 4.

Environment. Parent-directed involvement was higher in the outdoor than indoor exhibit (Ms = .61, .40), $F(1, 55) = 8.22$, $p = .01$, $\eta_p^2 = .14$. Parents showed equally high rates of child-guided involvement, $F(1, 55) = 1.09$, $p = .30$, $\eta_p^2 = .02$, and equally low rates of uninvolvement with their children at both exhibits, $F(1, 55) = 2.17$, $p = .15$, $\eta_p^2 = .04$.

Form. Across both environments, child-guided involvement was highest at replica ($M = .81$) and playground ($M = .83$) forms compared to activity station ($M = .68$)

Table 4. Parent involvement by exhibit form, function, and play structure ANOVAs.

Design category	Main effect *F*-value/ η_p^2	Exhibit design element *mean (SE)*				Interaction *F*-value/η_p^2
Form	*df* (3, 165)	Technology/ nature	Replica	Activity station	Playground	X environment
Uninvolved	3.75* .06	.08[a] (.03)	.15[ab] (.04)	.20[b] (.04)	.13[ab] (.04)	3.96* .07
Indoors		.15[ab] (.04)	.11[a] (.06)	.23[b] (.06)	.18[ab] (.05)	
Outdoors		.01[a] (.04)	.19[b] (.06)	.16[b] (.05)	.08[ab] (.05)	
Child-guided	9.98*** .14	.64[a] (.05)	.81[b] (.04)	.68[a] (.04)	.83[b] (.04)	1.35 .02
Parent-directed	7.27*** .12	.64[a] (.05)	.40[b] (.05)	.45[b] (.05)	.49[b] (.05)	0.47 .01
Function	*df* (3, 165)	Instructional	Interactive	Constructive	Active	X environment
Uninvolved	6.96*** .11	.04[a] (.01)	.10[b] (.03)	.17[c] (.03)	.10[b] (.03)	0.25 .01
Child-guided	8.33*** .13	.78[ab] (.04)	.73[ac] (.04)	.68[c] (.04)	.86[b] (.03)	11.61*** .18
Indoors		.87[a] (.06)	.68[bc] (.06)	.56[c] (.06)	.79[ab] (.05)	
Outdoors		.69[a] (.06)	.77[a] (.05)	.80[a] (.05)	.92[b] (.04)	
Parent-directed	6.39*** .10	.64[a] (.04)	.56[ac] (.05)	.50[bc] (.04)	.43[b] (.05)	0.64 .01
Play structure	*df* (2, 110)	Free play	Guided play	Directed play		X environment
Uninvolved	6.87** .11	.15[a] (.04)	.13[a] (.04)	.04[b] (.01)		0.68 .01
Child-guided	2.83 .05	.80[a] (.03)	.70[a] (.04)	.78[a] (.04)		8.97*** .14
Indoors		.74[a] (.05)	.62[a] (.06)	.87[b] (.06)		
Outdoors		.87[a] (.05)	.77[ab] (.06)	.68[b] (.06)		
Parent-directed	7.96*** .18	.46[a] (.04)	.55[b] (.05)	.65[b] (.05)		3.30* .06
Indoors		.37[a] (.07)	.58[b] (.07)	.58[b] (.06)		
Outdoors		.54[a] (.06)	.51[a] (.07)	.72[b] (.06)		

Note. Row means that share a common superscript do not differ significantly.
*$p < .05$.
**$p < .01$.
***$p < .001$.

and technology/nature ($M = .64$) forms, and parent-directed involvement was highest with technology/nature exhibit forms ($M = .64$) compared to the other forms, ($M_{replica} = .40$, $M_{station} = .45$, $M_{playground} = .49$). Uninvolved parenting was most common at activity station ($M = .16$) and replica ($M = .19$) compared to nature ($M = .01$) forms outdoors but was least common at replica ($M = .11$) compared to the activity station ($M = .23$) forms indoors.

Function. Across both environments, parent-directed involvement was highest with interactive ($M = .56$) and instructional ($M = .64$) functions and lowest with active functions ($M = .43$), and uninvolved parenting was lowest at instructional functions ($M = .04$) and highest at constructive functions ($M = .17$). Child-guided involvement was most common at active functions ($M = .92$) compared to all other functions outdoors ($M_{instruct} = .69$, $M_{interact} = .77$, $M_{construct} = .80$), but child-guided involvement was equally high at active ($M = .79$) and instructive ($M = .87$) functions indoors.

Play structure. Across both environments, uninvolved parenting was lowest at directed play structures ($M = .04$) compared to free ($M = .15$) and guided ($M = .13$) play structures. Child-guided involvement was highest at directed play structures indoors ($M = .87$), but lowest for directed play structures outdoors ($M = .68$). Outdoors, child-guided involvement was highest for free-play structures ($M = .87$). Parent-directed involvement was lowest for free play structures ($M_{indoors} = .37$, $M_{outdoors} = .54$) compared to both guided ($M = .58$) and directed ($M = .58$) play structures indoors but only compared to directed play structures outdoors ($M = .72$), where parent-directed involvement was particularly high.

Interim summary: parent involvement. Overall, parent-directed involvement was highest at the outdoor exhibit, where it was observed particularly often at directed play structures but was similarly facilitated by technology/nature forms and instructional functions at both indoor and outdoor exhibits. Child-guided involvement was observed at a high rate overall but was highest at replica and playground forms, active functions and indoor instructional functions, and outdoor free play structures and indoor directed play structures. Uninvolved parenting was observed at a low rate overall but was highest at constructive functions, free and guided play structures, and was particularly low at nature forms outdoors.

Discussion

This study provides a unique perspective on how multiple elements of exhibit design—form, function, play structure—promote child engagement and parent involvement at both indoor and outdoor exhibits at a local science center. As expected, exhibit environment had little unique impact on engagement and involvement, suggesting that children and parents have enriching experiences in both environments despite the differences in the prevalence of exhibit designs (e.g., more technology inside, more nature outside). Across both exhibit environments, and consistent with our predictions, interactive functions and free play structured exhibit elements facilitated high levels of child engagement (i.e., duration and frequency). Also consistent with our predictions, free play structures and replicas facilitated pretend play, and parent-directed involvement was highest at technology/nature, instructional, and directed play structure exhibit elements.

The results from this study illustrate that exhibit environment contributed to observed differences in child and parent behavior when considered in combination with exhibit design elements. Specifically, these results suggest a potential tradeoff between exhibit designs that increased parent involvement (e.g., instructional and directed play exhibit elements) and those that enhanced the level of children's engagement in both pretend play and sharing behaviors (e.g., replica and active exhibit elements). Taken together, these findings indicate that exhibit designs offer different affordances and there is not a one-size-fits-all approach to engagement and learning in play-centered exhibits. We consider the implications for educators, museum organizers, and parents, all of whom seek to balance child autonomy with overall family engagement in naturalistic play-centered learning experiences.

Indoor and outdoor environments: More similarities than differences

Despite differences in the prevalence of technology and nature exhibit forms, and certain types of exhibit designs (Appendix A), our findings suggest that indoor and outdoor play-centered exhibits equally promoted engagement, pretend play, sharing, and most levels of parent involvement. Both technology and nature exhibit forms were appealing and highly engaging to children despite often being conceptualized at opposite ends of the design and play spectrum. Children's high level of engagement with technology exhibit forms is consistent with accumulating empirical evidence that technology is

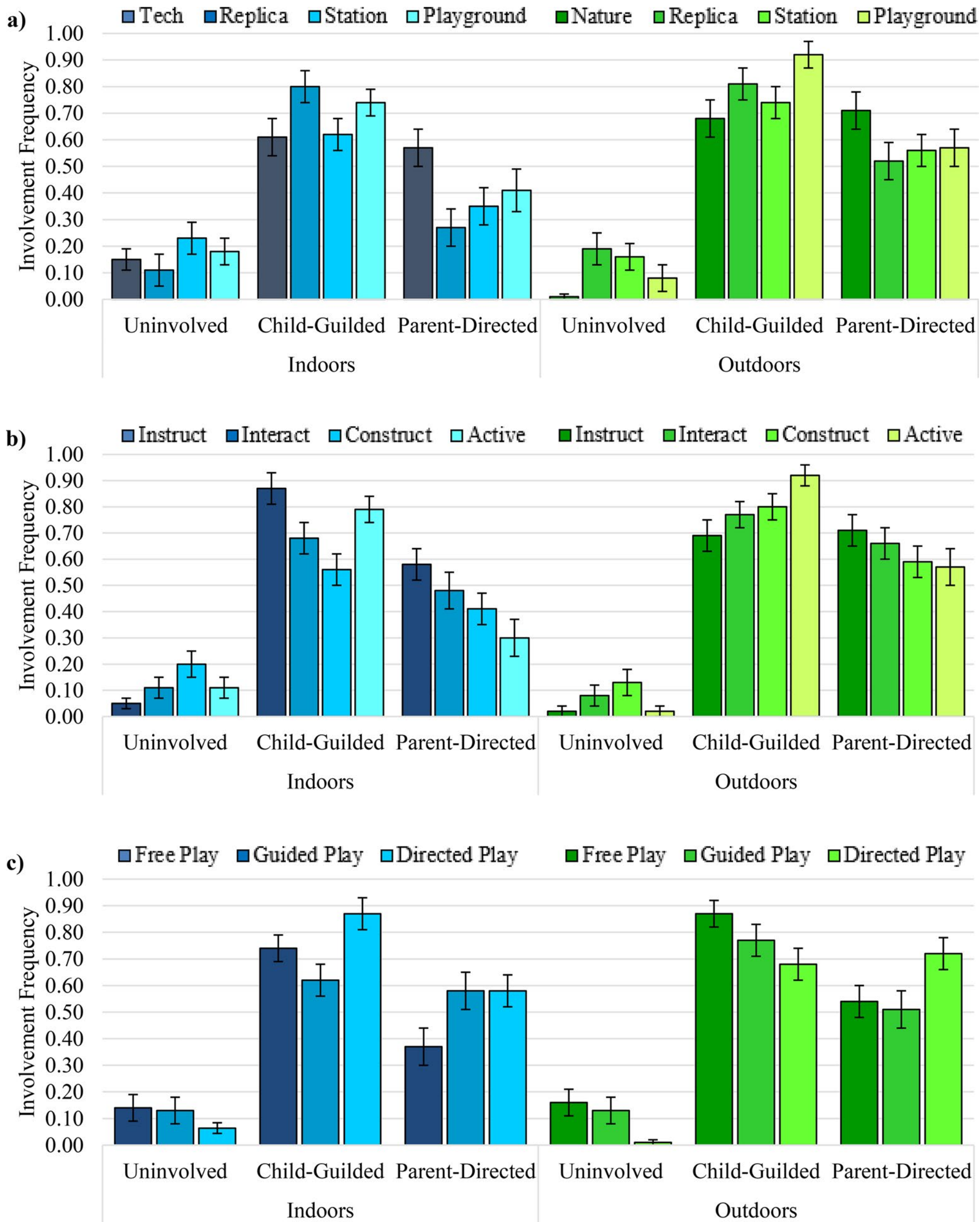


Figure 4. Parent involvment by exhibit environment: (a) form, (b) function, and (c) play structure. Notes: Station = activity station. Error bars show standard errors.

particularly attractive to and engaging for children (Druin, 2009; Markopoulos et al., 2008; McKnight & Cassidy, 2010; Rideout, 2013). Children's high level of engagement with nature exhibit forms aligns with evidence that experiences with nature can cultivate a sense of wonder (Schinkel, 2017). We speculate that the level of engagement and amount of time that families spent at technology and nature features indicate that both promoted novel, appealing, and salient experiences. In turn, these data suggest that certain experiences with novel technology may share properties with the nature experiences that readily attract and intrinsically motivate children to learn.

One additional finding from this study that may support this idea is that replicas were equally engaging for children in both environments, despite their differences. For example, the pirate ship in indoor SciPlay Bay had fish sensor lights and signal lights, and the submarine had buttons that could be pressed that made various noises. There was not an equivalent attractive nature component in the Jeansboro Junction replicas, yet children continued to be attracted to the replica exhibits in the outdoor environment. Perhaps the attraction to replica forms had to do with the presence of their interactive and active exhibit elements, as both interactive and active functions were highly engaging across environments. Indeed, technology and playground forms also featured these functions, which may be why they elicited high levels of child engagement (see Appendix A). Relatedly, the nature forms that were interactive rather than purely instructional (e.g., the animal barn, petting zoo) were visited more frequently and for longer periods. Exhibits with interactive features have been found to promote greater attentional interest and engagement (Degotardi et al., 2019; Ganea et al., 2011; Markopoulos et al., 2008) and young children enjoy physical activity and playground structures (Bagot et al., 2015; Pellegrini & Smith, 1998).

In contrast to exhibit forms that leverage interactive and active functions to promote engagement, activity stations had the lowest child engagement (frequency), and particularly inside (duration). Relative to other exhibit forms, activity stations were structured with clear educational objectives. For example, the weaving and weigh stations both were intended to teach specific skills or concepts that could be challenging for young children to master without substantial caregiver scaffolding. The low rates of engagement at these stations are consistent with previous work in which children prefer less structured educational activities (Singer et al., 2006; Van Schijndel et al., 2010). Constructive functions, which heavily overlapped with activity station forms, were the least popular across exhibit environments. Although many previous museum-based studies have focused on exhibits that facilitate scientific learning and have constructive elements, results from the present study suggest that children and their parents may not naturally choose these activities over interactive options during visits to play-centered exhibits. Unexpectedly, parent involvement was lower at activity stations and constructive functions across both environments. This finding is particularly noteworthy given that parent–child conversations during activities that leverage constructive elements can promote science learning (Benjamin et al., 2010; Callanan et al., 2020; Willard et al., 2019).

Results from the present study suggest that parents were relatively successful at modulating an appropriate level of involvement according to the exhibit context. In this way, parents may be engaging in appropriate scaffolding regardless of experimentally directed or naturalistic exhibit interactions. Across environments, we found low rates of uninvolved parenting and high rates of parent-directed involvement were observed at technology/nature, instructional, and directed play structure exhibit elements. Parents provided more directive parenting at exhibit elements with clear learning objectives or more complex technological features that required parental guidance. For example, one technology station consisted of a hand-controlled marionette projection that required focused coordination and motor skills to select and operate characters and scenes. Although children are increasingly adept at using tablet-like devices (Druin, 2009; Rideout, 2013), the novelty of technological exhibit features may have prompted higher levels of parent involvement. Indeed, parents continued to be engaged with their children at less structured exhibit elements but allowed their children to guide those interactions. Child-guided involvement was observed at high rates across many design elements, but particularly replicas, active, and outdoor free play structured exhibit elements. The prevalence of child-guided involvement at these elements may have been particularly important for the facilitation of pretend play given that overly intrusive parenting is linked to lower quality pretend play (Youngblade & Dunn, 1995).

Pretend play was observed most frequently at replicas, a prominent form in both environments that were specifically designed to facilitate pretend play by encouraging children to use the provided apparatuses and materials to take on different roles and create rich narratives as they explored aspects of the real world that are otherwise inaccessible to them (Jant et al., 2014; Lillard et al., 2013). The finding that children engaged in high rates of pretend play at replicas suggests that children engaged with the replicas as they were intended. Replicas were mostly comprised of free play structure features and many also included active features (e.g., run around the pirate ship, climb on animals), which suggests that pretend play at replicas likely accounts for the pretend play prevalence at active, free play structure exhibit elements. In general, free play structures do not provide children with guidelines on how to interact with the exhibit element, leaving children the opportunity to create and act out rich pretend narratives. Notably, we did not find evidence of age differences in pretend play. Most developmental research on pretend play focuses on the preschool years, but these results suggest that older children continue to engage in and benefit from imaginative play in environments specifically designed to foster pretend play.

In addition, sharing was observed at higher rates at free play structure exhibit elements, including replicas. Interestingly, sharing was also observed at activity stations and constructive functions in both exhibit environments. Although not originally hypothesized, one possible reason for this finding is that, like replicas, activity stations and constructive functions contained numerous materials for children to complete the intended activity. For example, Palm Tree Fort in SciPlay Bay had pool noodles and beach towels that could be used to build a fort. These materials seemed to encourage sharing just as the materials provided at replicas encouraged sharing and pretend play.

Environment and design element interactions: Notable differences

Overall, the indoor and outdoor exhibits were more similar than they were different. Several important interactions between environment and various design elements provide detailed insight into the effect of exhibit design on families' science center experiences. Parent-directed involvement was the only environment-level difference; it was observed at higher rates in the outdoor exhibit compared to the indoor exhibit. Parent-directed involvement may have been particularly common outdoors due to the presence of live animals. All the live animal exhibit elements were considered directed play structures, which were the most frequently visited play structure in the outdoor environment. Children engaged more frequently with parent-directed and instructional elements in the outdoor environment than in the indoor environment. There were also more directed play structures in the outdoor compared to the indoor exhibit, providing parents with more opportunities to engage in parent-directed involvement.

In addition, the live animal exhibit elements all contain signage as a way for visitors to engage with the exhibit independently. As a result, parents may have relied on signage to address children's questions or direct their engagement in these areas. These patterns of engagement and parent involvement outdoors may provide an example of how children's outdoor exhibit exploration promotes a better understanding of key concepts related to the environment and biodiversity (e.g., Chipeniuk, 1995; Strife & Downey, 2009). Live animals served to capture children's interest and foster engagement, perhaps because of the unique and salient opportunity for direct encounters with them (LoBue et al., 2013). Parent-directed involvement may have been the best method to leverage children's interest to promote learning about nature whereas free play or child-guided play may have been best to capitalize on children's engagement to promote learning indoors.

By comparison, the only directed-play structure in the indoor exhibit was the Tai Talk, an educational and interactive show that uses Live Performance Animation. Parents are not responsible for guiding their children's learning experience at the Tai Talk in the same way that they scaffold their children's learning at the live animal exhibits. Although parents may have encouraged their children to watch the show, or directed their attention, the level of directing was lower than what was observed at the outdoor exhibit. Instead, parents were more likely to actively watch their children while they were engaged with the show, which in turn contributed to differential patterns in child-guided involvement by play structure and environment. Because Tai Talk was only available at scheduled times, directed play structures were visited less frequently than the directed play structures in the outdoor exhibit. However, the show format of the Tai Talk encouraged visitors to engage with the exhibit element longer than the self-guided, traditional live animal exhibits. Consequently, participants spent significantly more time at instructional functions and directed play structures indoors.

Another notable difference between the two environments is that children spent more time at playground forms and active exhibit elements outdoors compared to indoors, and these exhibit elements only facilitated pretend play and sharing outdoors. In addition, parents were more likely to be uninvolved at indoor playground forms while parents were more likely to engage in child-guided involvement at outdoor active functions. Some of these differences may stem from the fact that all of the outdoor playground/active exhibit features were part of a replica exhibit element, Fair Fun. The see-saw, for instance, had saddles for seats and could have encouraged children to pretend like they were riding horses. In contrast, the playground and active exhibit elements indoors were only partially tied to replica forms. Parents may have been more involved with their children in the outdoor exhibit because they were taking part in their children's pretend play narratives. The replica qualities of the outdoor playground and active features may have also encouraged children to engage longer, even though playground and active exhibit elements were visited at the same rate across environments.

We speculate that these observed differences between the indoor and outdoor exhibits are more than a product of the exhibit elements chosen to be included in each play-centered exhibit; they are also a function of the environment itself. The outdoor exhibit environment was less "contained" than the indoor exhibit and parents may have felt the need to be more involved and directive with their children outdoors due to practical concerns such as child safety. Outdoor environments also encourage more physical movement, which may have facilitated longer engagement with the active functions (Pellegrini & Smith, 1998). The presence of multiple live and interactive animal exhibit elements is also inherently a part of the outdoor environment, as a technological instructional show is inherently part of the indoor environment.

Taken together with the similarities between the two environments, these findings suggest that both the indoor technology-focused and outdoor nature-focused exhibits facilitated child engagement and parent–child interactions during family visits to the science center. However, the two environments offer unique elements that differentially foster positive outcomes. Children may be more likely to engage with instructional material outdoors due to their interest in live animals, while they may be more drawn to free-play structures indoors. Parents, in turn, modulate their involvement based on the activities that most attract their children's attention.

Transactions with child engagement, parent involvement, and exhibit design

The results from the current study suggest that there are tradeoffs between child engagement, parent involvement, and exhibit design. These tradeoffs suggest that there is no one correct way to engage with play-centered exhibits in informal learning settings. Engagement with multiple different types of exhibit designs may provide the richest experience at play-centered exhibits, but parents could also tailor the experience based on their family's interests and goals during a specific visit. If families are only interested in learning about animals, then they would benefit from the outdoor, interactive, live animal exhibits but may forgo the replicas. If families are more interested in providing their children with opportunities to be active, explore, and play, they may be drawn to the free play structure exhibit elements such as replicas and playgrounds. Children's autonomous exploration and engagement in free play and their parent-directed interactions with technology and nature may both potentiate positive outcomes due to the benefits of parent scaffolding or the intrinsic motivation to learn fostered by children's natural interest in interactive, free play (Ryan & Deci, 2000; Zosh et al., 2018).

Although learning outcomes were not assessed in the current study, our results provide insight into the exhibit designs that promote the optimal conditions for learning in naturalistic settings. These insights translate into several practical implications for exhibit design for play-centered exhibits. Below, we discuss ways that our findings speak to how nuances in exhibit-level and parent–child level transactions can be harnessed and integrated to promote visitor engagement and learning outcomes in naturalistic settings.

Engagement in informal learning environments: Implications for educational exhibit design

A balance between the unique aspects of both indoor and outdoor play may help museum organizers enhance families' opportunities to facilitate a rich variety of naturalistic learning experiences for their children. Indoors, technology in this context of exhibit design brings something qualitatively and quantitatively different than technology in children's everyday lives (e.g., tablets). Its natural appeal for children should be used to promote engagement and learning. In a similar manner to technology, children appeared captivated by the opportunity for direct encounters with live animals while they explored the outdoor exhibit, which may have made the concept of biodiversity personally salient. Any opportunity for science centers and museums to integrate outdoor experiences, particularly with live animals, may be an important avenue for increasing children's desire to learn about pressing environmental topics or interest in environmental careers (Strife & Downey, 2009; Wells & Lekies, 2006).

Further, the differences in play structure that emerged between indoor and outdoor environments may be informative for museum and science center organizers who seek to cultivate variety in or balance between the types of parent- versus child-guided experiences offered. It is undoubtedly important for children to engage in both autonomous exploration and parent-scaffolded exploration, as both promote positive developmental outcomes uniquely (Zosh et al., 2018). Therefore, our findings suggest that the potential tradeoff between exhibits that promote child-guided versus parent-directed experiences should be considered carefully to ensure that play-centered spaces achieve the desired balance between the two forms of exploration.

Across exhibits, constructive functions were the least popular and did not appear to be intrinsically attractive or motivating for children. They also yielded lower levels of parent involvement. Yet constructive functions provide children with opportunities to learn about specific topics such as engineering, physics, and causal structures, particularly when appropriately scaffolded by parents (e.g., Benjamin et al., 2010; Callanan et al., 2020). Informal learning centers should explore ways to promote both parent and child engagement with constructive exhibit elements. One potential way to do so would be to pair constructive functions with more popular exhibit design forms such as technology, nature, or replicas. Constructive functions may also benefit from additional signage or conversation prompts to provide parents with the necessary context to promote appropriate scaffolding (Benjamin et al., 2010; Jant et al., 2014).

In addition, our findings speak to the possibility that in a play-centered space with a lot of activities to offer, those features that involve interactivity might capture children's interest and engagement most immediately and could be leveraged to promote many forms of learning (e.g., social as well as content-based). Among all exhibit designs, functions, and play structures, interactive elements were most systematically and robustly associated with engagement, pretend play, sharing, and parent involvement across environments. On the surface, these results suggest that museums and science centers should incorporate interactive exhibit features whenever possible. However, there are limits to the utility of interactive features. For example, too much interactivity in museum exhibits can distract visitors from the intended use of the exhibit, make exhibits overly complex and difficult to use, and fail to convey the educational content of the exhibit (Allen & Gutwill, 2004). In addition, the overuse of interactive features can hinder children's innovative exploration and the development of creativity (Zheng et al., 2007). Therefore, although interactive exhibit elements were the most engaging for children in the current study, the incorporation of such features should be used in moderation and considered in context with the overarching learning goal of the exhibit.

Limitations and future directions

One potential limitation of this study is that we narrowly focused on two child engagement behaviors that were relevant to the play-centered context of the target exhibits. More work is needed to examine the different forms of engagement, play, and prosocial behavior. For example, Van Schijndel et al. (2010) examined how more nuanced forms of exhibit exploration including object manipulation, repetition, and variation of use, were affected by differences in parent involvement. In their study, parent involvement predicted more sophisticated forms of child engagement, which suggests it is important to not only examine how parent involvement interacts with engagement, but how it affects the quality of the engagement. Future work should also consider a broader range of prosocial behaviors (e.g., helping) to determine if associations vary according to different exhibit characteristics, especially considering that various prosocial behaviors fail to correlate with each other (e.g., Dunfield et al., 2011).

Similarly, we observed parent interactions with children that focused on parents' surface-level involvement with their children at each exhibit. Although similar involvement categories were used in previous research (e.g., Medina & Sobel, 2020) and notable differences were observed in parent involvement by exhibit design, a more detailed examination of parental behavior could provide additional information. For example, the "parent-directed" category did not differentiate between parenting behaviors that were necessary due to context (e.g., child age and exhibit element) and those that would have been considered overly intrusive, or parenting behaviors that directed children away from other rich forms of exploration. However, the exhibit design features that promoted parent-directed versus child-guided forms of involvement (e.g., directed play versus free play exhibits) suggest that parents engaged in both forms of involvement in mostly appropriate and expected ways. Importantly, we do not assert that one form of parent involvement (child-guided or parent-directed) is inherently better than the other, nor did we assess how individual differences in parent involvement predicted learning outcomes. The results of the study show that parents may modulate their involvement level based on multiple facets of exhibit design, which provides an important foundation for examining how more detailed parent behaviors interact with exhibit design to predict child learning outcomes in the future.

As with most existing research on this topic and consistent with the science center membership demographics, the observed families largely represented middle-income European American backgrounds. Accordingly, findings for parent involvement and child play may not generalize to other sociocultural settings. Parents' perspective of their own involvement in children's exploratory play varies across cultures and community contexts (Gaskins, 2008; Roopnarine, 2011). Additional research is needed to examine the extent to which children's educational play and learning in museum settings differ based on cultural variation in parent–child interaction, including whether maternal and paternal associations differ and have unique effects on children's engagement (e.g., Tamis-LeMonda et al., 2004).

Although the naturalistic, observational design was a strength of the current study, consequently potential confounding variables were beyond our control. For example, we did not control for the number of visitors present in the exhibit areas during any observation sessions, which could have limited children's opportunities to share or possibly engage in pretend play. Parents could have also steered their children away from particular exhibits if they were too crowded. Similarly, many participating families included siblings in addition to the target child, but due to equipment limitations, recorded observations focused on interactions with the target child. The presence of siblings could have affected children's engagement, pretend play, and sharing, particularly if the target child viewed the sibling as a familiar playmate and someone to interact with while engaging with the exhibit elements. Parents may have also changed their level of involvement in the presence of siblings. Future research should expand observations to encompass siblings, especially given that sibling characteristics and family relationships are related to individual differences in the frequency and complexity of children's pretend play (Youngblade & Dunn, 1995). Additionally, certain exhibit elements were either removed during data collection (i.e., the outdoor see-saw) or were only available at specified times (e.g., Tai Talk). These occurrences were a consequence of the observational, naturalistic design of the study that the research team did not have control over but may have affected the engagement data nonetheless. Relatedly, the naturalistic study design was limited by the necessity of researcher intervention to recruit families and equip participants with microphone packs, which introduced possible social desirability bias on parent or child behavior.

Conclusion

The current study extends research on child learning in museums and science centers by providing an account of how a variety of exhibit design aspects promote engagement, pretend play, sharing, and parent involvement in two play-centered exhibits. Although learning outcomes were not measured, the findings of the study demonstrate that exhibit design features differentially encourage child and parent engagement, which in turn may translate to learning. The findings further demonstrate that there is not one optimal design that facilitates all forms of engagement; different design features promoted different types of child engagement (including pretend play and sharing) and parent involvement. These differences, however, did not always extend across different exhibit environments. Despite the differences in technology and nature-based features, the indoor and outdoor exhibits both facilitated engagement, pretend play, sharing, and parent involvement. Thus, this work contributes valuable information to museums and science centers because it gives insight into the types of exhibit designs they can employ in play-centered areas to achieve particular engagement goals.

Notes

1. Engagement frequency reflects the average number of unique engagement episodes with an exhibit element across participants. A low number indicates that the exhibit element was not visited frequently by our participants as a group while a higher number indicates that the exhibit element was visited frequently by our participants as a group.
2. Because technology forms were only in the indoor exhibit and nature forms were only in the outdoor exhibit, the two forms were combined into one variable for analyses. Any differences in technology and nature forms are captured by the interaction between environment and form.

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Disclosure statement

There are no potential conflicts of interest to report.

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Appendix A: SciPlay Bay Exhibit Elements: Engagement & Classifications

Table A1. SciPlay Bay exhibit elements: engagement and classifications.

		Engagement		Design categories		
SciPlay Bay exhibit elements		Frequency *M(SD)*	Duration (min:sec)	Form	Function	Play structure
1.	**Pirate Ship**	**--**	**4:03**	**3**	**2**	**1**
1.1	Run around ship	.30 (.54)	---	5	4	1
1.2	Ship props	.63 (.63)	---	3	2	1
1.3	Fish light sensors	.37 (.57)	---	1	2	2
2.	**Musical Octopus**	**--**	**1:50**	**3**	**2**	**1**
2.1	Drums	.81 (.68)	---	1	2	1
2.2	Harp	.30 (.54)	---	1	2	2
3.	**Marionette**	**.44 (.51)**	**2:09**	**1**	**2**	**2**
4.	**Submarine**	**--**	**3:29**	**3**	**2**	**1**
4.1	Press buttons	.96 (.71)	---	1	2	1
4.2	Periscope	.48 (.58)	---	1	2	2
4.3	Steering wheel	.63 (.69)	---	3	2	1
4.4	Windows	.37 (.49)	---	3	4	1
5.	**Tai Talk***	**.19 (.40)**	**3:49**	**1**	**1**	**3**
6.	**Coral Puppets**	**.48 (.58)**	**1:09**	**4**	**2**	**1**
7.	**Food Truck**	**.93 (.78)**	**2:41**	**3**	**2**	**1**
8.	**Flying Colors**	**.93 (.73)**	**3:33**	**1**	**2**	**2**
9.	**Building Blocks**	**.26 (.59)**	**1:26**	**4**	**3**	**1**
10.	**Palm Tree Fort**	**.52 (.64)**	**2:08**	**4**	**3**	**1**
11.	**Shark Head**	**.63 (.69)**	**1:01**	**3**	**4**	**2**
12.	**Sand Slide**	**.85 (.82)**	**1:30**	**5**	**4**	**1**

Note.
*Tai Talk only available during scheduled performance times. Bolded exhibit elements were the superordinate exhibit elements. They may contain features that differed by design category. Due to methodological constraints, duration data was only collected for these exhibits. Form: 1 = Technology, 3 = Replica, 4 = Activity Station, 5 = Playground. Function: 1 = Instructive, 2 = Interactive, 3 = Constructive, 4 = Active. Play structure: 1 = Free, 2 = Guided, 3 = Directed.

Table A2. Jeansboro Junction exhibition elements: engagement and classifications.

		Engagement		Design categories		
Jeansboro Junction exhibit elements		Frequency *M(SD)*	Duration (min:sec)	Form	Function	Play structure
1.	**Farmhouse**	**.60 (.68)**	**2:48**	**3**	**2**	**1**
2.	**Wishing Well**	**.27 (.79)**	**1:50**	**3**	**2**	**2**
3.	**Fair Fun**	--	--	3	2	1
3.1	Animal care props	.43 (.57)	2:11	3	2	2
3.2	Fair fun playground*	.70 (.99)	4:16	5	4	1
4.	**Mulch Pit**	**--**	**4:40**	**2**	**2**	**1**
4.1	Farm figurines	.50 (.63)	--	3	2	1
4.2	Play mulch	.17 (.46)	--	2	2	1
5.	**Weigh Station**	**.10 (.31)**	**0:50**	**4**	**1**	**2**
6.	**Weaving Station**	**.23 (.50)**	**1:51**	**4**	**3**	**2**
7.	**Garden**	**.33 (.54)**	**0:38**	**2**	**1**	**3**
8.	**Bunnyville**	**.60 (.50)**	**0:48**	**2**	**1**	**3**
9.	**Chicken Coop**	**.90 (.66)**	**0:52**	**2**	**1**	**3**
10.	**Animal Barn**	**1.33 (.88)**	**3:37**	**2**	**2**	**3**
11.	**Petting Zoo**	**.63 (.62)**	**5:31**	**2**	**2**	**3**
12.	**Peacocks**	**.47 (.63)**	**1:10**	**2**	**2**	**3**
13.	**Howler Monkey**	**.57 (.57)**	**1:25**	**2**	**1**	**3**
14.	**Coati**	**.43 (.50)**	**0:57**	**2**	**1**	**3**
15.	**Bees**	**.30 (.47)**	**0:48**	**2**	**1**	**3**

Note.
*Fair Fun playground contained a seesaw for the first six participants. For the remained 24 participants, Fair Fun playground consisted of "lifesize" plastic animals meant to be climbed on. The two exhibit elements were combined for the purpose of analysis. Bolded exhibit elements were the superordinate exhibit elements. They may contain features that differed by design category. Due to methodological constraints, duration data was only collected for these exhibits. The only exception is Fair Fun; the duration data was collected for each exhibit feature separately. Form: 2 = Nature, 3 = Replica, 4 = Activity Station, 5 = Playground. Function: 1 = Instructive, 2 = Interactive, 3 = Constructive, 4 = Active. Play structure: 1 = Free, 2 = Guided, 3 = Directed.