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Connecting play experiences and engineering learning in a children's museum

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ABSTRACT

This study examined whether and to what extent children's prior play experiences might support engineering learning in museum's building construction exhibit. 277 families with 4 to 9-year-old children worked together to solve the first engineering design problem, and then children worked alone to solve the second. At the outset, some families received a demonstration of a key spatial engineering principle - bracing - that was relevant to both problems, and some were informed of the second problem before beginning the first, to increase the likelihood of knowledge transfer. More spatial play experience was associated with better family problem solving success, and when combined with the demonstration, better success by the children problem solving alone. More creative play experiences combined with the engineering demonstration to lead to greater family problem solving success. Results suggest that certain types of play experiences can help children make better use of engineering learning opportunities.

1. Introduction

Play is critical for young children's learning (Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009) and can foster skills that are foundational in STEM - science, technology, engineering, and mathematics (e.g., Honey & Kanter, 2013). Moreover, in informal educational environments such as museums, hands-on play and conversations with adults can advance STEM learning opportunities for children (e.g., Bell, Lewenstein, Shouse, & Feder, 2009; Benjamin, Haden, & Wilkerson, 2010; Callanan & Jipson, 2001; Jant, Haden, Uttal, & Babcock, 2014; Palmquist & Crowley, 2007; Paris & Hapgood, 2002; Rigney & Callanan, 2011). Nevertheless, we know relatively little about the connections between children's play experiences at home and early informal STEM learning in museums. This issue is important because all learning involves bridging what is already known and familiar and what is new to learn (NRC, 1999). Understanding what kinds of prior play experiences can prepare children when new learning opportunities arise may also be very helpful in thinking about ways to best support children's learning across educational contexts (e.g., home and museum; home and school). In this project, we asked parents to report on the play activities their children engage in frequently at home. We examined whether and to what extent variations in play experiences, and the knowledge these experiences might engender, connect with children's engineering problem solving in a building construction exhibit in a museum.

1.1. Play and learning

Piaget (1962) described play as a primary way that children interact with materials in the environment and construct knowledge about the world. Vygotsky (1967) emphasized that in play children interact with other people and can learn from them. Contemporary studies have further suggested important connections between play and children's cognitive development. For example, children who play more have better language and literacy skills (e.g., Han, Moore, Vukelich, & Buell, 2010; Weisberg, Zosh, Hirsh-Pasek, & Golinkoff, 2013), stronger executive function skills (e.g., Barker et al., 2014; Diamond & Lee, 2011), and may be more curious and creative thinkers (Hoffmann & Russ, 2016; Schulz & Bonawitz, 2007). However, debates about the evidence for linkages between play and learning (see e.g., Lillard et al., 2013; Weisberg, Hirsh-Pasek, & Golinkoff, 2013) highlight that it is important to consider both the amount and variety of different types of play that can support learning of specific kinds of skills.

1.2. Engineering learning

We focus on engineering learning for a number of reasons. Engineering emphasizes STEM-relevant problem solving, including defining a problem, considering different solutions, testing hypotheses, and generalizing across examples, and these are skills that can be

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fostered through certain play activities as well. Engineering integrates science and mathematics in ways that can be accessible and interesting to young children (Haden, Cohen, Uttal, & Marcus, 2016; Sullivan, 2006). Also, like many play activities, when children participate in engineering design and problem-solving, they usually engage in a combination of object manipulation and social interaction with others (Bucciarelli, 1988; Cunningham, 2009; Haden et al., 2016; Liu & Yu, 2004; NRC, 2009). Many children and adults possess limited understanding of key engineering principles, such as structural integrity and bracing (e.g., Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Davis, Ginns, & McRobbie, 2002; Gustafson, Rowell, & Rose, 2001; Knight & Cunningham, 2004; Marcus, Haden, & Uttal, 2017), but they can learn and make use of engineering-relevant information that is provided even through very brief demonstrations in a museum (Haden et al., 2016; Marcus et al., 2017). Relevant prior play experiences may further help support understanding of such demonstrations. This later point motivates us to consider potential synergistic, interactive effects of children's prior play experiences and engineering information provided at the museum on problem solving at the museum.

1.3. Connecting play and engineering learning

From our perspective, play that promotes spatial skills, or mentally manipulating information about objects in the environment, may be especially crucial for promoting engineering learning. For example, in *puzzle*, *math*, *and board game play*, there are opportunities to estimate, measure, balance, construct analogies, and so forth, that may be critical in advancing engineering learning (Casey & Bobb, 2003; Verdine et al., 2014). Likewise, *construction play*, such as with Legos and blocks, can increase spatial abilities while offering specific opportunities for children to engage in principles and practices of engineering. Research on block, puzzle, and board game play to date has focused on links to children's mathematical performance (Ginsburg, 2006; Jirout & Newcombe, 2015; Levine, Ratliff, Huttenlocher, & Cannon, 2012; Mix, Moore, & Holcomb, 2011; Siegler & Ramani, 2009; see Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2017, for review). However, the same spatial skills that construction, and block and puzzle play can advance may also be relevant to engineering problem solving, particularly when the problems require use of spatial engineering principles, such as diagonal bracing to stabilize a structure (NRC, 2006). Indeed, the notion of the importance of spatial knowledge for children's engineering finds further support in experimental work linking spatial skills training to engineering problem solving activities much like the ones used in this study (Gentner et al., 2016; Ramey & Uttal, 2017).

Other forms of play that do not specifically involve engineering may nevertheless bolster skills that can either directly or indirectly impact engineering learning. For example, *creative play* – including art, music and pretend and fantasy play – can promote imagination and what-if and analogous thinking, as well as symbolic representational skills (Gardiner, 2000; Reed, Hirsh-Pasek, & Golinkoff, 2012) that are inherent to the engineering design process. Some types of *technology play* can promote spatial skills, although perhaps less so than hands-on spatial play activities (e.g., puzzles, block play, construction) for young children (Newcombe, 2010; Uttal et al., 2013). Moreover, although further work is certainly needed to draw definite conclusions, a growing body of work demonstrates linkages between *physical play*, cognitive functioning and behavioral self-regulation, and academic achievement (e.g., Becker, McClelland, Loprinzi, & Trost, 2014; Diamond & Lee, 2011). This being said, associations between play and engineering learning have not been extensively examined; this is a focus of the present study.

1.4. Transfer of knowledge

Importantly, connections between play and learning hinge on children understanding and representing the knowledge that play engenders in a way that makes it useable and applicable when new relevant opportunities for learning arise. Cognitive scientists refer to this as *transfer of knowledge*, and it is evident, for example, when a child uses what was learned on one problem to solve other related problems (Bransford & Schwartz, 1999; Goldstone & Son, 2005; Klahr & Chen, 2011). Psychological research suggests that transfer is often difficult or fleeting when it happens at all (Gick & Holyoak, 1983; Ross, 1989), and few studies of object manipulation and early learning have consistently found transfer to new contexts (Marcus et al., 2017; McNeil & Uttal, 2009; Uttal et al., 2013; Uttal, Liu, & DeLoache, 2006; Uttal, O'Doherty, Newland, Hand, & DeLoache, 2009). Nevertheless, Holyoak and colleagues' work with children and adults (e.g., Gick & Holyaok, 1980; Holyoak, Junn, & Billman, 1984) suggests that it is sometimes possible to prompt successful transfer by simply pointing out that what is learned in one context or problem can be used to solve the problem at hand.

We consider three aspects of transfer. First, we ask how prior play experiences at home might enhance engineering problem solving in a museum setting. Second, we investigate if certain types of play experiences help children make better use of a key engineering principle that is demonstrated to them to solve engineering problems at the museum. Third, we consider if by explicitly prompting transfer we might be more likely to observe it across the two building problems that we presented to families at the museum.

1.5. The current study

A focus on the linkages between play and engineering learning guided our efforts in the current study. Parents were surveyed about how often their children engaged in 12 different kinds of play experiences that spanned five domains (cf. Zosh, Fisher, Golinkoff, & Hirsh-Pasek, 2013): (1) *puzzle*, *board and math game play*, (2) *construction play*, (3) *creative play*, (4) *technology play*, and (5) *physical play*. Associations between these types of play and children's engineering problem solving in a children's museum were examined.

In the museum, parents and children worked together to solve the first engineering design problem, which for half of the families was to stabilize a wobbly skyscraper, and for the other half was to stabilize a wobbly bridge. The children worked alone to solve the second problem, which was to fix the structure (skyscraper or bridge) they had not worked on with their parents. Because the same engineering principle was implicated in fixing both structures – the wobbly bridge was the same structure as the wobbly skyscraper, but turned on its side – transfer of learning was relevant across the two engineering problems for all children. Half of the children and families were introduced to the second engineering problem prior to beginning the first – a condition we called *Anticipated Transfer*. The other half of the families in the *No Anticipated Transfer* condition did not learn of the second engineering problem until they had finished the first.

Another experimental manipulation involved providing some families with information about the key spatial engineering principle – bracing – prior to working on the two problems. With this we asked if certain play experiences at home would support children's understanding and use of the demonstration of bracing when solving one engineering problem with their parents and one on their own. Prior to working to solve the two engineering problems in the museum exhibit, half of the children and their families observed a demonstration of bracing. These children in the *Engineering Demonstration* condition had the chance to test how bracing stabilizes structures. The other half of the families in the *No Engineering Demonstration* condition were not provided with any engineering-related information or experiences in the museum prior to building. We examined if the demonstration alone, and/or in combination with children's play experiences, might lead to more use of the spatial engineering principle when building at the museum.