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Nature by Design: Playscape Affordances Support the Use of Executive Function in Preschoolers

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Abstract

Playscapes are intentionally designed, dynamic, vegetation-rich, play environments that nurture young children's affinity for nature. We investigated how the affordances of a nature playscape provide opportunities to strengthen children's executive function by identifying examples of goal-directed and focused problem-solving within children's free play in this setting. Through video-based fieldwork, drawing on the extant literature, and application of indicators within existing assessments for executive function in nature preschools, we found that playscapes can be executive function-enhancing environments, as children are likely to set their own goals, problem-solve, self-regulate, focus attention, and demonstrate cognitive flexibility while playing in these settings. Future directions call for follow-up evaluation studies to more robustly substantiate initial findings.

Keywords: goal-directed behavior, self-regulation, executive function, nature playscapes, early childhood environments, play

E. O. Wilson (1984) asserted that humans have an innate emotional affiliation with other living organisms, a complex behavior he termed *biophilia* that persists from generation to generation. He argued that removal from nature does not deter this affinity, but that it persists, "atrophied and fitfully manifested in the artificial new environments into which technology has catapulted humanity" (Wilson, 1993, p. 32). Kellert (1993) further supported the biophilia hypothesis, suggesting that our relationship with nature is indicative of the "human evolutionary dependence on nature as a basis for survival and personal fulfillment" (p. 44). Subsequently, biophilia and related views became an underlying premise for Louv's treatise, *Last Child in the Woods* (2005). Louv expertly points out that children born after 1964 are more removed from nature than any prior generation, creating a phenomenon he termed *nature deficit disorder*. This book sparked grassroots movements for connecting children to nature as evidenced by an increase in articles related to nature and children (see Children & Nature Network https://www.childrenandnature.org/research-library/) and hundreds of self-identified nature-oriented programs around the world listed on the North American Association for Environmental Education's Natural Start Alliance website (see http://www.naturalstart.org/).

The trending arguments for connecting children to nature, however, have not diminished the building of traditional, packaged, metal and plastic playgrounds for young children. The traditional playground in the USA and other countries consists of equipment that has one purpose, such as swinging, climbing, or sliding. This equipment is embedded in a mulched or rubberized flat fall surface. To address this gap between nature play, which addresses nature-deficit disorder, and traditional playgrounds, Carr and Luken (2014) proposed a new paradigm for outdoor spaces in child care centers and preschools. They suggest that *playscapes*—nature-rich landscapes and ecologically designed play spaces for young children—replace the rubberized and unchallenging uni-level flooring and plastic climbing equipment common in most playgrounds.

Playscapes are unique environments designed to offer children opportunities to explore and learn through playful interactions with natural loose parts and elements that afford engagement with both the natural environment and peers. Activities are child-directed and, at times, adult-supported. Our research has provided evidence that self-determination, inquiry, and science learning occur organically within playscapes and that children are engaged there longer in comparison to traditional playgrounds (Carr, 2014; Kochanowski & Carr, 2014; Wight, Kloos, Maltbie, & Carr, 2016).

The current study describes how preschool-aged children engage in free play on nature playscapes. We assert that well designed playscapes afford authentic opportunities for children to demonstrate goal-directed behavior and self-regulatory skills. We set forth the argument that these behaviors signify *executive function* (EF), an umbrella term for self-regulation skills (Berk & Meyers, 2013), and suggest that free play within playscapes provides opportunities for preschool children to exercise their EF skills.

Play and Playscapes

If play is primordial (Huizinga, 1955) and biophilia has an evolutionary basis (Wilson, 1984), then playing in nature should be quite satisfying for children, and it appears to be so. Although the functions of play are often ambiguous (Sutton-Smith, 1997), as Huizinga (1955) proclaims, play is driven by intrinsic phenomenological satisfactions. Research indicates that play is essential for healthy brain development (Brown, 2009), that children are not getting adequate access to nature-oriented play spaces in early care and education programs (Louv, 2005), and that nature has tremendous benefits for children (Chawla, 2015). Although these arguments clearly support the acute developmental and academic need for play, child-initiated play in early childhood programs is waning due to push-down curricula, standardized testing, and prescriptive, didactic instruction (Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009; Miller & Almon, 2009). Furthermore, children in schools, child care programs, before- or after-school care, or other educational settings, may or may not have access to play in natural environments. Even when playground time is provided, many school settings have little to no natural plantings or artifacts, but are instead comprised of manufactured playsets and mulched or rubberized fall spaces. Hence, transforming playgrounds into playscapes is a pragmatic and ecologically sound approach to regularly engaging children in nature play (Carr & Luken, 2014).

Playscapes, as defined by the Cincinnati Nature PlayScape Initiative, are intentionally designed to be dynamic, vegetation-rich, play environments that nurture young children's affinity for nature (Luken, Carr, & Brown, 2011). They are purposefully planned to reflect the larger ecosystem by using native plantings and creating affordances (Gibson, 1979; Heft, 1988) that encourage children to take risks, explore, and investigate while engaging in active, sensory, collaborative, and dramatic play. In addition to abundant plantings and a well-defined boundary, they typically include pathways, water features, hiding spaces, loose parts, gardens, bird blinds, unleveled topography, and spots to dig, build, gather, and store materials (Moore, 2014). Integral to the flexible playscape environment are natural loose parts (e.g., tree cookies[1], logs, sticks, stones, soil, sand, shovels, buckets, magnifying glasses, etc.) to foster creativity, exploration, problem-solving, and more complex play scenarios (Brown, 2003; Nicholson, 1972). Examples of features and affordances within the two playscapes used in the current study are shown in Table 1. These features and affordances provide opportunities for symbolic and pretend play experiences, which may facilitate the development of self-regulated thought (Berk & Meyers, 2013). Design features and loose parts may promote flexibility within complex play interactions (Brown, 2003; Luken, Carr, & Brown, 2011; Nicholson, 1972).

[1] A "tree cookie" is a disc-shaped, lateral slice of wood cut from a log.

Table 1. Features and affordances within the two playscapes used in the current study

Feature	Description	Affordances
Creek/Water Feature	Man-made water features emulate natural creek beds found in the region.	Rocks, sticks, soil, and sand provide a multitude of loose parts for exploration and experimentation.
Landscape Designs	Varied topography reflects the local terrain, including meadows, woods, wetlands, etc.	This variety affords different types of play and provides navigational challenges, as well as an opportunity to interact with native plantings found within each unique area.
Entry/Gathering Space	A central meeting spot acts as a landmark to reconvene. A map of the playscape is located near the entrance.	Maps and a designated gathering space assist children in orienting themselves within the playscape and often prompts children to make decisions about where they would like to play and provides a mapped path to get to that spot.
Pathways	Pathways, including primary, circular paths, as well as secondary, and tertiary paths.	Paths help children navigate the playscape and aid in spatial awareness.
Perimeter Boundary	The boundary, which is designed to blend with the surroundings, provides the security many adults find necessary outdoors.	Boundaries facilitate a more free-range environment necessary for exploration and problem-solving.
Gravel/Sand Pits	Open-ended play in designed spaces.	Digging, sifting, burying, collecting, creating, etc. often engages children in social interactions, collaboration, and problem-solving. It is a sensory experience that invites participation.
Play Structures	Play structures on both playscapes are open-ended and blend with the natural landscape.	Examples such as log forts and platforms elicit a variety of play themes and support a wide range of developmental levels.
Hiding Spaces	Child-size spaces such as caves and tunnels, as well as naturally occurring features such as high grasses.	These spaces offer respite and are also ideal venues for imaginary play.

This study investigates how play in natural environments also provides opportunities for goal-directed and focused problem-solving, which are directly related to the development of effective learning skills (Zelazo, Blair, & Willoughby, 2016). We argue that the intentional design and affordances of playscapes provide a particularly ideal milieu for promoting the development of more domain-general cognitive capabilities of EF, in addition to more domain-specific knowledge and skills related to Science, Technology, Engineering, and Mathematics (STEM) learning.

Executive Function

Although there are a variety of conceptualizations, we employ Zelazo's (2015) definition of EF as "the set of self-regulatory skills involved in the conscious goal-directed modulation of thought, emotion, and action" (p. 56). Cognitive complexity and control theory-revised (CCC-r) proposes that EF is a functional construct involving processes that are used in motivated, goal-directed problem-solving, such as problem representation, planning, execution, and evaluation (i.e., error detection and correction) (Zelazo, Carter, Reznick, & Frye, 1997; Zelazo, Müller, Frye, & Marcovitch, 2003). Components of EF described in the literature (e.g., Zelazo, 2015) typically include cognitive flexibility (i.e., considering multiple ways to represent and solve a problem, taking the perspective of others, and making inferences), working memory (i.e., selecting and keeping goals, information, and plans in mind and using them to guide cognition and behavior), and inhibitory control (i.e., focusing attention, ignoring distractions, and suppressing responses).

Diamond and Lee (2011) provided evidence that repeatedly engaging in activities with progressively increasing challenges such as games, computerized training, aerobics, martial arts, yoga, mindfulness, and school curricula improves children's EF skills. They also noted that more holistic approaches to intervention that also address emotional, social, and physical development are likely to be more effective than those that narrowly focus on specific EF skills. According to Zelazo (2015), because of the relatively high level of brain plasticity, "the preschool period may be a window of opportunity for the cultivation of fundamental EF skills via well-timed, targeted scaffolding and support" (p. 64). Repeated experiences of reflection in the context of goal-directed problem-solving increase the effectiveness of EF skills and the efficiency of corresponding neural circuits in the anterior cingulate cortex (ACC), orbitofrontal cortex (OFC), and hierarchically arranged regions of the lateral prefrontal cortex (ventrolateral PFC, dorsolateral PFC, and rostrolateral PFC; Zelazo, 2015). These brain regions and their associated functions undergo rapid growth and are especially responsive to environmental influences during the preschool years. Espy and colleagues (2016) concluded that there is a qualitative shift in the organization of executive function between the ages of three to five. They found that at around the age of four-and-a-half years, executive control emerged as a specific factor on tasks, indicating increasing differentiation of function with age and experience. Other research has provided evidence for rapid age-related changes in attention, cognitive flexibility, and inhibitory control skills during early childhood (Carlson, 2005; Clark et al., 2013; Jones, Rothbart, & Posner, 2003; Posner, Rothbart, Sheese, & Voelker, 2012; Wiebe, Sheffield, & Espy, 2012; Zelazo et al., 2003).

The preschool years are an ideal period for children to engage in free play in natural environments that are intentionally designed to provide opportunities for goal-directed problem-solving. Yet, few studies of the relationship between these types of experiences and the development of EF skills have been conducted. As noted by Carlson, Faja, and Beck (2016), although laboratory measures (see Carlson, 2005) and inventories asking parents and teachers to rate preschoolers' EF skills in their daily lives are available for preschoolers, including the Child Behavior Rating Scale (CBRS; Bronson, Goodson, Layzer, & Love, 1990), Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), and the Behavior Rating Inventory of Executive Function—Preschool version (BRIEF-P; Gioia, Espy, & Isquith, 2003), observational measures of EF appropriate for use within playscapes are not currently available. Moreno, Shwayder, and Friedman (2017) described the assessment of EF during preschool as precise, but "mostly disembodied from actual behaviors that preschoolers might engage in naturalistically within preschool settings" and stated that "we have yet to establish what executive function looks like—and more importantly how to encourage it—in common, spontaneous preschool activities" (p. 144).

In this study, we addressed the research question, *What components of EF might preschoolers use while engaging in free play in intentionally-designed natural environments (i.e., playscapes) that provide opportunities for goal-directed problem-solving?* We used an exploratory approach that involved defining components of EF and selecting and describing video-taped observations of children engaging in goal-directed problem-solving at two playscapes. Operational definitions of the following components of EF from the BRIEF-P were used to label behaviors during problem-solving on playscapes: Inhibitory Control, Flexibility, Emotional Control, Initiation, Working Memory, Planning and Organization, and Monitoring (see Roth, Isquith, & Gioia, 2014 for an overview). The operational definitions of these components were used, rather than the items themselves, because they provide general descriptions of behaviors that can be applied to a wide range of contexts, whereas some individual items refer to specific contexts that are not relevant to real-time observations of play and problem-solving in natural environments (see Table 2). The components are consistent with Zelazo (2015) and colleagues' (1997; 2003) conceptualization of EF described above, with the addition of Emotional Control and Initiation. Regarding Emotional Control, Zelazo and Cunningham (2007) suggested that emotion corresponds to the motivational aspect of cognition and therefore, when emotional regulation occurs as a means to solving a primary problem, then EF involves emotional control. Regarding initiation, Lezak (1982) noted that translating an intention into productive activity requires the capacity to initiate sequences of behavior (also see Anderson, 2002; 2008) and that the capacity to carry out purposive behavior is often not seen in structured tasks measuring EF skills.

Methods

This video-based fieldwork study (Jewitt, 2012) is part of a larger NSF Pathways concurrent mixed-methods research project. Video records of three naturally occurring events are the data sources. For this study, vignettes were created from a purposeful sampling of video data to depict how the affordances of a playscape may strengthen EF in children ages 3-5 by providing opportunities to use goal-directed behaviors. Vignettes can transcend social science research with high levels of internal and ecological validity, particularly when they represent real situations and include visual content and conceptual boundaries as these vignettes do (Hughes & Huby, 2004). Specifically, observing the interplay of the child-environment relationship (Wapner & Demick, 2002), we investigated how the structure of the playscape, and the affordances within, impacted the interactions and actions of the children's play (Jewitt, 2012). The analyses were conducted by four scholars in the fields of educational psychology, early childhood education, and developmental and learning sciences.

Setting

Two demonstration playscapes, a .23 acre playscape intended for children ages 3-5 on the University of Cincinnati campus (Arlitt PlayScape) and a 1.6 acre playscape intended for children up to approximately age 10 at Cincinnati Nature Center, were built using the principles set forth by the Cincinnati Nature PlayScape Initiative (Luken, Carr, & Brown, 2011) and the design guidelines and creative direction of Robin Moore, Professor of Landscape Architecture at North Carolina State University (Moore, 2014). These playscapes serve as affordance models for community replication. They also serve as the research sites for participating preschool classrooms. Figures 1 and 2 provide a sample view of the playscape sites.

Figure 1. Arlitt PlayScape

Figure 2. Cincinnati Nature Center PlayScape

Participants
Sixty-five children, ages 3-5, from two different and diverse programs, were involved in this research. The first program is an urban university laboratory preschool serving children who are funded through Head Start or tuition fees. The second program is a large, non-profit program serving low-income children and families at multiple sites across suburban and rural settings. The four participating classrooms (two from each program) were designated by the program director based on logistical factors and teacher willingness to participate. For this exploratory study, teachers were asked to refrain from interacting with the children unless an intervention was needed to ensure their safety. The programs visited the playscapes separately, with approximately 33 children playing in the playscape per videotaping event. In addition to data collection dates, children from the urban laboratory preschool had daily access to the campus playscape. Children from the other program did not have this benefit, however, both playscapes are open to the general public, so children may have visited with their families or guardians outside of program hours.

Data Collection
For the NSF Pathways research from which the vignettes for the current study are taken (Carr, 2014), numerous tools were employed to explore how children were playing and learning in playscapes (video, audio, individual science learning assessment, behavior mapping). Data were collected over an 18-month period. Three trained videographers, who were spaced throughout the playscape, focused on observed instances of engaged free play (independent or group) where children appeared to be immersed in activities resembling inquiry, exploration, or

imaginative play. Video data were collected using a guiding protocol for when and how long videotaping episodes were gathered. For example, videographers were to continue taping until the play scenario waned, the children moved to a new space, or the children changed activity. Videographers were trained to be as unobtrusive as possible during data collection so as to not interfere with the children's play.

Data Analysis

Video segments were viewed and coded for date, time, location, activity, science learning, loose parts, and play categories such as functional, constructive, dramatic, and games with rules. Video logs were created that include brief narrative summaries that were used to select videos for transcription into vignettes. The three vignettes included in this exploratory study were detailed to provide an expanded narrative about the children's play scenarios. As noted above, EF was defined using Cognitive Complexity and Control Theory-revised (Zelazo et al., 2003). Key behaviors were labeled using operational definitions of components of EF adapted from the BRIEF-P, shown in Table 2, (Roth, Isquith, & Gioia, 2014).

Table 2. Operational definitions of components of executive function from the BRIEF-P adapted from Roth, Isquith, and Gioia (2014)

Component	Definition
Inhibitory Control	Ability to control impulses and stop one's behavior
Flexibility (Shift)	Ability to flexibly solve problems by making transitions from one situation, activity, or aspect of a problem to another, switch or alternate attention, and change focus from one mindset or topic to another as the circumstances demand
Emotional Control	Ability to modulate emotional responses
Initiation	Ability to begin a task or activity and independently generate ideas, responses, or problem-solving strategies
Working Memory	Ability to hold information in mind for the purpose of generating goals or plans and completing a task or generating a response, including implementing a series of actions and following complex instructions
Planning & Organization	*Planning* includes the ability to anticipate future events, set goals, and develop appropriate steps ahead of time to carry out a task or activity, which often requires sequencing a series of actions or responses and obtaining any necessary tools or materials necessary to complete the activity *Organization* includes the ability to bring order to information, actions, or materials to achieve a goal
Monitoring	*Task monitoring* includes the ability to keep track of what is working and not working and assessing one's own performance during problem-solving *Self-monitoring* includes the ability to keep track of one's behaviors and its effects on others

Results

Researchers selected vignettes providing examples of EF-related behaviors during goal-directed problem-solving, and extracted still photos from the videotapes. To maintain confidentiality, the names of children and adults have been changed.

Vignette One

The following vignette describes Taylor crossing the stream at a playscape by walking across a log (Figure 3).

Figure 3. Child using a log to cross a stream in a playscape

After watching the child in front of him successfully walk across a semi-damp log, Taylor took his first steps forward (A). Almost immediately, both feet slipped and he ended up sitting on the log, legs straddling off each side (B). Taylor sat for a moment swinging his legs a bit and looking around at the other children climbing on rocks or playing in the stream. Looking ahead toward the end of the log, Taylor leaned forward and began scooting his body across the log, squeezing the log with his legs and using his upper body to inch towards the other side of the stream-bed (C). After scooting his body forward several inches, Taylor leaned over, pushed himself up on his hands

> *and knees (D), and then, moving cautiously, stood up straight on top of the log (E). With arms and hands slightly bent out to his sides, Taylor focused his gaze and walked steadily to the end of the log (F). After reaching the end of the log, Taylor stood briefly with a slight smile on his face, scanning the area where classmates were playing nearby. In a moment he was off to another location of the playscape.*

This vignette provides a clear illustration of goal-directed problem-solving that created opportunities for exercising EF skills. Taylor observed another child cross the stream by walking on the log and was motivated to cross the stream in the same way. After taking a few steps, demonstrating *initiation*, he slipped, which appeared to lead Taylor to pause, reflect, and to reason about how prevent himself from slipping again, indicating *flexibility* and *planning*. He showed persistence by attempting to cross the log again. Taylor seemed to adjust his stance by bending his arms and hands to provide better balance, showing *task monitoring*. He demonstrated directed attention by focusing his gaze. Taylor showed concentration until he achieved his goal, perhaps indicating use of *working memory*, and appeared to experience a positive emotion (i.e., joy or pride) when he reached the end of the log. This is a behavioral example of goal-directed modulation of thought, emotion, and action.

Vignette Two

The following vignette describes Evelyn and Francesca rolling a heavy log (see Figure 4).

Figure 4. Children rolling a heavy log at a playscape

> *A group of children were engaged in activity at the log fort. Children were rolling small logs across the leaf-covered ground towards the fort, some were carrying logs into the fort, others were climbing on the walls of the fort, and several children were using rakes to pile up leaves. Evelyn walked away from the group of children at the log fort where she had been playing. She ventured over to a large log lying in the woods. Bending over and pressing her hands down on the log, she began to lean in with her entire body and roll the log forward (A). It appeared to be challenging for Evelyn to initially get the log to roll. Leaning with her body nearly horizontal to the log while pushing against it, Evelyn's feet slipped on the leaf-covered ground. She recovered her stance quickly. After successfully rolling the log several feet, the log ran up against something on the ground that caused it to stop moving. Evelyn's feet slipped out from under her a second time and she fell forward on her hands and knees onto the ground in front of her.*
>
> *Evelyn repositioned herself and successfully rolled the log a few more inches before it came up against another obstacle making it difficult to roll any further. In a quick motion, Evelyn stood up straight, briefly looked around, then quickly turned her body so the log was behind her. She lowered herself down onto the log while simultaneously pulling her arms back and placing her hands on the log behind her. At this point, Evelyn was sitting against the side of the log, hands placed behind her, pushing against the log (B). She was successful in rolling the log another foot from this position before coming to a stop.*
>
> *Francesca, a classmate, walked up and joined Evelyn. Facing the log, both children began pushing against the log with their hands, attempting unsuccessfully to roll it forward (C). Next, Evelyn walked around to the other side of the log and began to push in the opposite direction. This change in direction caused Francesca to lose her balance and topple backward onto the ground facing the log with her feet out in front of her. Francesca then put her feet up on the log and began pushing. At one point Evelyn was pushing the log in one direction with her hands, while Francesca was on the ground using her feet to push the log in another direction. The children persisted with this interaction for a few moments until Francesca walked around to Evelyn's side of the log and sat on the ground to push the log with her feet. Evelyn joined Francesca in sitting on the ground. Both children braced their hands against the ground behind them and rolled the log forward using their feet until the log stopped rolling (D). This time, Evelyn stood up, brushed herself off and walked away.*

Similar to Vignette One, the children in Vignette Two were engaged in goal-directed problem-solving by attempting to roll a large, heavy log, showing *initiation*. Evelyn appeared to be motivated to move the log towards the fort. Her first strategy, trying to push the log with her hands using the force of her body, worked until an obstacle prevented the log from rolling further and caused her to fall. Evelyn persisted by repositioning her body so that the log was behind her, which shows *task monitoring*, *planning*, and *flexibility*. When Francesca joined Evelyn, they became engaged in joint-attention and collaborative problem-solving. Their first joint strategy of pushing the log with their hands was not successful. When Evelyn walked around the log and pushed it with her hands in the opposite direction causing Francesca to fall and to then try pushing the log with her feet, both children showed *task monitoring*, *planning*, and *flexibility*. As their final strategy, both children pushed with their feet from the same side of the log. As the children collaborated in this problem-solving activity, now using their feet as coordinated problem-solving tools, they demonstrated how the task required an environment structuring activity, an example of *organization*.

Vignette Three

The following vignette describes children stacking tree cookies at a playscape (Figure 5).

Figure 5. Stacking tree cookies at a playscape

Yasemin stood beside her completed construction project—a tower created by stacking tree cookies one on top of the other. Yasemin had gathered the tree cookies from various areas of the playscape and carried them to a site with level ground located along the side of a main pathway. Initially spreading individual tree cookies out on the ground in a semi-circle fashion, Yasemin built the tower using the largest tree cookie as the base, followed by stacking progressively smaller tree cookies to a height just above her head. Throughout the construction process Yasemin used her hands to gently make minor adjustments to the log slices positioned in the top third of the tower, which was leaning in a precarious manner (A).

Richard, one of the teachers, arrived at the construction site and was standing in close proximity, observing Yasemin and her tower of tree cookies. Richard spoke briefly with Yasemin. With an inflection of admiration in his voice, he inquired, "You just carried them?" Yasemin replied matter of factly, "Yes, from the playscape." Richard responded with, "Wow!", again the tone of his voice expressing how truly impressed he was by her tenacity and planning skills. Turning to walk away, Richard commented to Yasemin, "It's leaning a little bit, yea." Yasemin began walking in a slow consistent pace, circling the leaning tree cookie tower. She extended her arms out as she circled, palms facing the tower rising four to five inches above her head, as if to catch wayward tree cookies should the tower begin to topple over. After several rotations around the tree cookie tower, Yasemin struck a pose that evoked a sense of accomplishment—clasping her hands at her chest. She appeared satisfied with her work at the playscape (B).

Next Yasemin sat down on a large rock facing the tree cookie tower hovering over her. She remained sitting, eyes fixed on the structure, hands resting in her lap as if contemplating what to do next. Richard had moved directly behind Yasemin as she perched on the rock, to interact with another child, Stacy. Noticing Richard and Stacy at the tree behind her, Yasemin stood up stating, "Oh, just one more leaf." She picked a leaf from the tree, walked to the tower and placed the leaf on top. Yasemin bent down quickly to retrieve the leaf as it drifted off the tower, replacing it back on top saying, "A hat!" At that point Richard commented, "Ah, decorations on top of there…" as he gestured toward the leaf perched on the tower. Yasemin, as she worked to position the leaf, immediately interjected, "Yea, this is a human so I'm putting a crown on her." Appearing content, Yasemin stepped back looking at her "human" with a smile on her face.

During another interaction, Richard stood next to the tower and commented on its height, indicating with his hand how tall it was compared to his side. Within minutes of observing Richard, Yasemin proceeded to compare the height of the tower to her own height. Standing tall with arms straight at her side she faced the structure. She moved her body in so close that her nose may have touched the edge of one of the tree cookies (C). Richard commented that the tower was taller than she was.

Nearing the end of the play session, Judith, another teacher, spoke with Yasemin about the process she used to build the tower. Judith, kneeling beside the tower commented, "You did this a couple different times…. I see you made some changes...that you realized you had a bigger one (tree cookie), and then you put the bigger one on the ground." In the end, with some prompting from a classroom teacher, Yasemin disassembled the tower so that others could have a turn playing with the tree cookies. She stated, "I'll take it down," then methodically began to lift two or three tree cookies off at a time, cautiously lowering them to the ground (D).

In this scenario, the non-uniform tree cookies required Yasemin to predict the stacking outcomes and create goals, demonstrating *planning* and *organization*, and attend to the task and follow through on the plan, possibly indicating the use of *working memory*. Yasemin showed *task monitoring* through her adjustments to log slices on the leaning tower, as well as seriation ability. We noted the similarities of this construction to the Tower of Hanoi (Simon, 1975) and London (Shallice, 1982) tasks, popular measures of EF, without restrictions on the number of moves and other rules. Yasemin appeared to show positive emotions regarding her completed tower. Higher-order thinking and *flexibility* is evident in her use of the tower to represent a person and the use of non-standard units to measure and compare her own height against the stack of tree cookies. Language related to the building process was elicited from Yasemin by Judith, which provides metacognitive support for Yasemin as she is asked to think, reflect, and recall what she did, engaging *working memory*. Collaboration and problem-solving is apparent in this playscape activity as are examples of Yasemin's *flexibility* and *inhibitory control* behaviors exhibited in the dismantling of the tree cookie tower, which also showed *self-monitoring* in her concern for other children's opportunity to build their own tower.

Discussion

Theorists, researchers, and teachers have long recognized the importance of EF to children's cognitive development, school readiness and achievement, and psychological well-being (e.g., Blair & Raver, 2015; Mischel, Shoda, & Rodriguez, 1989; Müller, Lieberman, Frye, & Zelazo, 2008; Vilgis, Silk, & Vance, 2015). Strong EF skills serve as a foundation for learning and adaptation to challenges encountered across a variety of contexts. EF skills and the reflective processes that underlie them jointly allow for more engaged, active, and reflective forms of learning (Marcovitch, Jacques, Boseovski, & Zelazo, 2008). EF skills are directly related to self-regulation (Berk & Meyers, 2013) and goal-directed problem-solving (Zelazo, 2015).

We believe that play in natural environments provides developmentally appropriate, authentic learning experiences. Because playscapes are designed to support these types of experiences, in this study, we addressed the research question, *What components of EF might preschoolers use while engaging in free play in intentionally-designed natural environments (i.e., playscapes) that provide opportunities for goal-directed problem-solving*? We believe that the affordances in well-designed playscapes, including built environmental elements and natural loose parts, provide opportunities for problem-solving that allow preschoolers to exercise their EF skills and potentially enhance them (Diamond & Lee, 2011; Moreno et al., 2017). We provided descriptions of children's play that demonstrates their use of specific components of EF as they engaged in goal-directed problem solving. Children showed inhibitory control, initiation, flexibility, working memory, planning and organization, and monitoring. Extrapolating constructs of EF using the limited existing tools, we found the affordances contained within the playscape—such as the logs, tree cookies, and risk-taking challenges—promote the use of EF skills. We did not describe an explicit example of emotional regulation; however, it is important to note that in two of the vignettes children seemed to experience happiness and/or satisfaction after engaging in successful problem-solving, and in all three vignettes, children did not demonstrate outbursts or high levels of frustration while engaging in their play activities, which may indicate some extent of emotional regulation.

Limitations and Future Directions

The current study was exploratory in nature. Our intent was to provide descriptions of play-based problem-solving in natural environments and to identify behaviors that may be indicative of developing EF skills. The significance of studying a playscape environment rather than general nature spaces is a playscape's potential link to preschool STEM curriculum and regularly scheduled experiences within playscape environments. In this way, teachers can plan integrated curricular experiences for facilitation of EF skills and children can engage in self-directed play where goal-directed problem-solving may occur. Significantly, researchers will have opportunities to investigate change over time, teacher efficacy and influences on EF skill acquisition, children's play and EF skill development, and the salient features of a playscape that foster EF skills. Moreover, the perimeter fence, paths, water features, physical challenges, plants, maps, etc. all warrant further study to determine how children are using them for goal-directed problem-solving. Our work is also subject to the inherent methodological limitations of video-based observations in the field, including, but not limited to, the decision-making of the videographer, recordings of short interactions, potential bias in the selection and description of vignettes from hours of video, and the lack of a valid and reliable protocol for measuring EF in natural environments. Thus, we cannot make strong conclusions regarding EF in natural environments based on the current study. Nonetheless, these descriptions are a first step that may provide a springboard for larger-scale studies of preschoolers' EF in natural settings.

Field studies on theoretical and developmental constructs that are difficult to measure in a laboratory present both reliability and validity issues. Further definition of key constructs is necessary before tackling practical and methodological challenges to conducting studies of children's developing EF skills in natural environments (Berk & Meyers, 2013). Once constructs and their definitions are identified, appropriate measures of EF can be related to play in natural contexts. Presently, researchers could correlate performance-based laboratory measures and inventories using parent and teacher reports of EF (see Carlson, 2005 for a review) of children's problem-solving in natural environments. Furthermore, there is a need for valid and reliable observational measurement of EF in real world preschool play contexts. Behavior-coding protocols for observations of EF skills used in play and problem-solving in natural environments could be developed, similar to the classroom-based work of Moreno and colleagues (2017). Numerous examples of high levels of children's problem-solving and EF skills are evident within our video archives and warrant description and investigation. These behaviors occur within the designed features of the playscapes, with the loose parts in the space, and through the children's free play activities. Furthermore, unlike a park or nature walk, the playscape provides a sense of place (Steele, 1981), which promotes specific experiences and evokes particular emotions based on the physical and social environment. Repeated visits create a sense of ownership and connection to the natural setting as the children mold the playscape environment to suit their preferences. More studies are needed to substantiate the role the environment plays in children's development of these emotions and skills.

Playscapes are designed for exploration, discovery, investigations, connection to nature, and play. The plant materials, loose parts, elements, and features in playscapes should reflect the local indigenous habitats in which they are built. If children are forming complex schemata, engaging in goal-directed behavior, and exhibiting self-regulatory skills while engaged in play, playscapes may serve as play and learning environments that allow children to exercise and further develop their EF skills. Furthermore, children's generalization of experiences may be more prevalent than those from playgrounds or even classrooms. Considering this possibility, playscapes as place-based educational environments for supporting foundational skills for children's EF are good investments for early childhood programs.

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