

The Role of Landscape Elements in Outdoor Learning Environment Design to Facilitate STEAM Learning in Early Years: A Case Study Approach

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Abstract

Children learn from their surroundings during the early years, and a diverse natural environment inherently affords informal STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning behaviors. Engaging in STEAM activities helps young minds not only appreciate and understand their environment but also enhances curiosity, questioning, exploration, discussion, investigation, reflection, and the formation of ideas and theories. Postulating that an outdoor learning environment designed with appropriate landscape elements for children ages 3-5 is associated with increased occurrences of STEAM-related behaviors and learning activities, the study utilized a nature-based preschool in Texas as a case study to test the hypothesis. During recess, we videotaped the play and learning behaviors of 171 children in 18 different play settings with multiple cameras and coded the video data using MAXQDA software. The findings reveal that children engage in STEAM-related activities in settings that offer varied and flexible affordances, such as sand and water play areas, loose parts play, and places with diverse natural topography.

Keywords: landscape elements, STEAM learning, affordances, video analysis

Introduction

Outdoor environments offer children opportunities to connect with nature and learn about their physical surroundings through activities such as exploring, experimenting, manipulating, practicing, changing, discovering, creating, and challenging themselves (Moore, 2006). From early childhood, children engage with their environment by experimenting with its functional properties relative to their own capabilities (Adolph & Kretch, 2015). Such exploratory behaviors of children are essential for perceptual-motor development. As children grow, their interaction with the environment evolves, highlighting the importance of designing spaces that support various developmental stages (Gibson, 2014; Heft, 1988). Many of these exploratory behaviors are associated with effective STEAM learning in the early childhood context. STEAM is the acronym for an educational approach that integrates Science, Technology, Engineering, the Arts, and Mathematics to advance critical thinking and problem-solving abilities of learners, essentially adding the "Arts" element to the traditional STEM fields to accommodate the spirit of creativity/imagination with critical thinking abilities, which are inseparable in the early years. Exposure to STEAM in early years is associated with enhanced appreciation of and interest in science (Aldemir & Kermani, 2017), later academic successes in math (Hunting et al., 2012), school readiness (Bustamante et al., 2017), and STEM/STEAM career interests in later years (DeJarnette, 2012). Considering the value of STEAM activities in the early years and the natural landscape's capacity to promote behaviors associated with STEAM, the design of outdoor environments needs to be reimaged to accommodate children's early informal learning behaviors.

We found the following concepts and theories useful in an in-depth understanding of the complex relationships between outdoor environments and STEAM learning behaviors.

Affordance Theory

Affordances are functional properties of the environment connected to the characteristics of the individual. The concept of affordance is crucial for understanding how individuals interact with their environments, as it refers to the opportunities for action that the environment provides (Gibson & Pick, 2000). This interaction is critical for development, especially in early childhood. This paper aims to elucidate the process by which children interact with these affordances within diverse natural settings, leading to a myriad of positive developmental outcomes such as STEAM learning. Human interaction with the environment operates within a constant and dynamic system, regardless of an individual's awareness (Heft, 1988). This interaction is facilitated through perceptual learning from infancy onwards. Through continuous interaction with environmental affordances, the perceptual system allows for the acquisition and refinement of motor and cognitive skills (Adolph & Kretch, 2015).

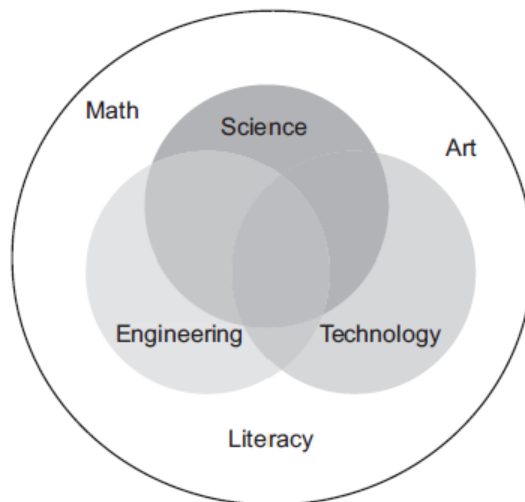
Affordances are universally accessible, transcending age, abilities, and cultural and physical differences (Gibson, 2014). Further, this inclusivity underscores the importance of designing environments that cater to diverse user needs, ensuring equitable access to developmental opportunities (Clark & Uzzell, 2002). The

landscape elements used to create an outdoor play and learning environment significantly impact how children perceive and utilize environmental affordances. Affordance permits children to correlate material properties with their actions (Miller, 2010; Trina, 2022). Effective design considers the arrangement of animate and inanimate objects and dynamic elements like air and water (Heft, 1988). By providing diverse stimuli, designers can facilitate rich, exploratory experiences that support perceptual learning and development (Clark & Uzzell, 2002). Thus, children with varying abilities interact uniquely with the same environment, necessitating flexible and inclusive design approaches (Gibson, 2014).

STEAM in Early Years

Although STEAM combines Science, Technology, Engineering, the Arts, and Mathematics, we perceive it as a collective learning framework in the context of early learning. While it is useful to separate these domains for observation and examination, children do not learn about their world in narrowly defined subject matter domains in their early years; rather, quality learning happens in the intersections and overlaps of the STEAM domains (Worth, 2019). It is useful to revisit the "Integration of STEM" diagram (Figure 1) as proposed by Karen Worth, which suggests the nature of this overlap and the need to integrate the STEAM domains.

Figure 1. The integration of STEM/STEAM by Karen Worth (2019)



STEAM learning capabilities and environmental affordances during the early years must be considered as "more extensive than the knowledge and skills associated with the individual STEM disciplines" (Murphy et al., 2019, p. 124). Rather, a range of behaviors and interactions with the environment inspiring problem-solving, design thinking, creativity, exploration, question and answer, and critical thinking are the core of STEAM in early childhood. These environmental affordances and individual capabilities are best nurtured in a learning environment that promotes hands-on, real-world contexts and presents learners with authentic problems to work on (Hefty, 2015). Our approach to early childhood STEAM in this research

aligns with this “collective” learning framework with overlapping environmental affordances and learning motivations/behaviors of children that work together to advance STEAM during the early years.

STEAM Behavioral Settings

Behavioral setting is a concept derived from ecological psychology, referring to the functional arrangement of environmental components (landscape elements) that support specific behaviors (Winkel et al., 2009). In designing for developmental phases, whether for children or adults, it is crucial to create settings that accommodate a wide range of activities and interactions (Loebach, 2005). Natural elements within designed environments, such as sand, water, and topographical variations, offer unique affordances that enrich children's science experiences. Such outdoor environment design connects children with nature and supports diverse learning and developmental opportunities (Kellert, 2012). Understanding these interactions can guide designers in creating natural play settings that promote STEAM learning opportunities and lifelong engagement with the environment.

Children’s outdoor play is linked with multiple developmental benefits (Louv, 2008). A rich outdoor play and learning environment is an essential element of childcare design that ensures children’s quality play and learning time in contact with daylight and nature. Innovative landscape design strategies are required to improve the quality of time spent outdoors in childcare centers where children spend most of their waking hours. The childcare center's outdoor play and learning area often serves as a modern substitute for the backyards of the past. However, these outdoor areas usually feature stand-alone play equipment set on a uniform grassy landscape, lacking diversity and connection to the essence of being outdoors (Herrington & Studtmann, 1998). Such designs primarily focus on physical development, overlooking children's social, emotional, and cognitive growth. There is a pressing need for design approaches that embrace these developmental aspects and integrate the distinctive qualities of outdoor environments to create enriching spaces for children (Herrington & Studtmann, 1998).

When designing play areas for children, it is crucial to consider the landscape elements that can be used for play. Allowing children to select their activities and shape their play environment is an essential aspect of their play experience (Chawla, 2015; Fjørtoft & Sageie, 2000; Moore, 1989). Intentionally designed outdoor learning environments encourage children to engage with nature, fostering creativity, problem-solving, and inquiry-based exploration (Harvey et al., 2020; Speldewinde et al., 2021). Bush kinders, for example, offer opportunities for hands-on learning using natural features such as trees, loose materials, and sensory-rich areas. These elements inspire curiosity and experimentation, essential for developing engineering, technological, and mathematical skills (Mawson, 2014). Intentionally designed natural play spaces also integrate sensory pathways, climbing structures, and water play areas, enhancing cognitive and physical development (Moser & Martinsen, 2010). Such environments enrich learning by connecting children with nature while nurturing essential STEAM skills.

Research Hypothesis and Research Questions

This research hypothesizes that outdoor learning environments in childcare settings, designed with appropriate landscape elements and offering diverse play and learning affordances, can increase occurrences of STEAM-related behaviors and STEAM learning, through:

1. STEAM concept development (e.g., a child builds a simple bridge with a plank, learning about balance and developing engineering concepts) and
2. STEAM learning activities (e.g., children engage in water play by creating channels in the sand and observing how water flows, promoting experimentation with cause and effect in physics—a science learning activity).

Our research questions were: a) How are different types of natural play settings associated with children's STEAM learning behavior occurrences? and b) Which play settings at the case study site are associated with STEAM learning affordances?

We expected that answering these research questions would enhance our understanding of the complex relationships between environmental affordances and associated learning behaviors to advance STEAM in early outdoor settings.

Research Method

Case study qualitative research was the preferred research strategy to answer the research questions. The case study is particularly appropriate for comprehending children's intricate STEAM learning behaviors in a versatile natural play setting. In a nutshell, the case study method enables researchers to retain the comprehensive and significant attributes of real-world events (Yin, 2003).

This study examines an existing naturalized outdoor setting where children engage in play and other self-initiated activities. It also investigates the importance of designing physical environments that provide rich play experiences to support STEAM learning and development. While outdoor play settings are pivotal for STEAM learning and STEAM concept development in early childhood (Trina et al., 2024), studying children's behavior in this context is challenging due to the need to conduct naturalistic observations in outdoor settings (Cutter-Mackenzie et al., 2015). Qualitative educational research has traditionally relied on methods such as observations, interviews, field diaries, and document analysis to study different aspects of children's interactions, learning, and development (Ukkonen-Mikkola & Ferreira, 2020). This study utilized video recording as a primary method to investigate preschoolers' STEAM behaviors and to identify their learning in an early childcare setting.

Overview of the Case Study Center

The Will Smith (WS) Zoo School in San Antonio, Texas, is a nature-focused preschool designed to connect young children with nature through its educational philosophy, teaching methods, classroom environment, and outdoor spaces. The school campus includes two acres where children spend a minimum of 50% of their day outside, engaging with natural materials like rocks, mud, water, sand, twigs,

and leaves. The school's landscape features a wide variety of plants and numerous outdoor play and learning settings (Figure 2), promoting nature play involving STEAM learning activities. This unique design, along with extended outdoor playtime, creates an ideal environment for studying how affordance-rich natural environments can provide diverse STEAM learning experiences.

Figure 2. Distinct play and learning settings of the Will Smith Zoo School, San Antonio, Texas



Figure 2, continued



This case study location encompasses a variety of play and learning environments, from which this research examined a total of 18 distinct settings. The integration of varying physical elements, such as climbing levels, rolling surfaces, jumping platforms, and sliding areas, promotes active physical play. These elements create a sense of both enclosure and openness, offering diverse spatial experiences at different heights. The inclusion of a large number of trees and shrubs within these environments adds aesthetic appeal and fosters creativity and STEAM learning opportunities. Some natural features provide spaces for dens, and some perform as practical tools in teaching children about environmental topics and seasonal changes. Additionally, materials like wood, water, sand, stones, and vegetation provide rich sources of both educational and creative stimulation. Natural features such as boulders and rocks enhance physical activity while encouraging imaginative, dramatic, and social play. Furthermore, the use of movable or loose parts extends beyond creating a tactile environment; it supports creative and imaginative play, offering children the chance to interact with and understand their surroundings more deeply.

Participants

Participants were 3–to 5-year-old children enrolled in the selected childcare center with parental consent. During this study, 171 children at the WS Zoo School were video recorded while playing in diverse play settings. The Human Research Protection Program of Texas Tech University authorized the IRB approval (IRB2021-489) for all data collection activities.

Data Collection Procedure: Video Recording

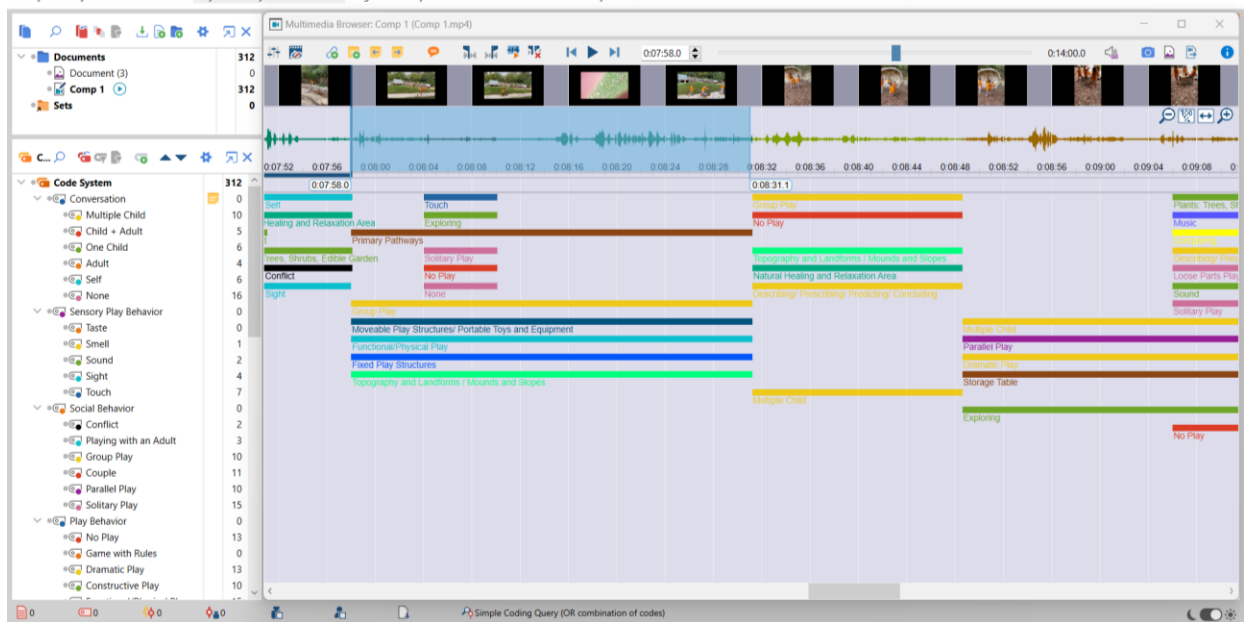
Researchers assigned random numbers to each participating child during the video data collection process. Children with parental consent for research participation but not for video recording wore tags with a distinctive red color so that the researchers could identify them easily during video data analysis. For collecting data, children were recorded for 2 hours and 48 minutes over two consecutive days during their free-play time at the school's outdoor learning landscape. These days were scheduled based on prior discussions with the childcare center's director. During video data collection, the research team members did not interact with children and observed passively. There was no interference with the children's and their teachers' daily outdoor activities. Video data was collected using fixed cameras (iPads and 360 cameras) and mobile phones (for closeup recordings of children's behaviors of interest during the experimental sessions).

Observational Data Analysis and Momentary Time Sample Recording

The primary challenge of all observation is extracting relevant data from a vast array of complex children's activities. To address this issue, we used time sampling observation (Hintze et al., 2002). This type of observation was applied to focus on a selected aspect of behavior to reveal the frequency of that behavior and to focus on an activity involving a child/group of children using a particular play setting, e.g., sand/water play area, to evaluate the appropriateness of the play setting.

Momentary time sampling recording is used when the observed behaviors are difficult to count. A behavior is challenging to quantify when it may be unpredictable or occur at a rapid pace, making it difficult to track. Because brief time sampling can underestimate the occurrence of a behavior, it may be more beneficial for documenting more frequent and long-term behaviors (Miller, 2010). For video analysis, this research used momentary time sampling recording, also called interval recording, in which behavior is examined throughout specific time periods (Miller, 2010). Momentary time sampling involves reviewing the recording to determine whether a behavior occurs or does not occur near the end of the interval.

For this study, we removed the recorded periods during which no activities were observed. The remaining video recordings from all the target areas (totaling 2 hours and 48 minutes at baseline) were segmented into 3-minute intervals. This resulted in a dataset of 312 observations of children in 18 target play settings, as sampled in Figure 3. We used MAXQDA video analysis software to assess the relationship between different play settings and children's STEAM activities (Figure 3).

Figure 3. Example of video coding and analysis in MAXQDA software

Coding for Video Analysis

Researchers applied different codes during the video data analysis, in categories including Existing Play Settings, STEAM Learning Behaviors, Types of Play Behaviors, Social Play Behaviors, Sensory Play Behaviors, and Conversation (Table 1).

This research examined a total of 18 distinct play settings in the case study location. The STEAM Learning Behavior category followed the findings of a scoping review paper (Trina et al., 2024). The category of Play Behavior Types used in this assessment was based on Smilansky's (1968) taxonomy (Loebach & Cox, 2020), with the addition of the "No play" category. Behaviors such as running and climbing were categorized as functional play for this study. We added a Sensory Play, or exploration, category to differentiate behaviors in which the focus of a child's actions appeared to be oriented more around what an object is than what can be done with it. The Social Play Behavior coding category describes a child's level of social engagement in play, while the Conversation coding categorizes their verbal interactions during play.

Table 1. Coding categories for video analysis of the existing outdoor play settings and children's behavior

Existing Play Settings	STEAM Learning Behavior	Types of Play Behavior	Social Play Behavior	Sensory Play Behavior	Conversation
<ul style="list-style-type: none"> •Sand Play •Water Play •Primary Pathways •Sensory Pathway •Plants: Trees, Shrubs, Edible Garden •Sensory Garden/ Grass Mazes and Tall Grass Areas •Large Blocks and Natural Construction •Loose Parts Play •Wildlife/ Bird, Butterfly, and Pollinator Habitat •Acoustic Play Settings •Art Area •Outdoor Classroom •Pretend and Performance/ Decks, Platforms and Stages •Topography and Landforms/ Mounds and Slopes •Multipurpose Lawn •Fixed Play Structures •Moveable Play Structures/ Portable Toys and Equipment •Natural Healing and Relaxation Area 	<p>Science + Technology + Engineering</p> <ul style="list-style-type: none"> •Observing •Exploring •Describing/ Prescribing/ Predicting/ Concluding •Hypothesis/ Cause and Effect/ Experiments •Asking Questions <p>Mathematics</p> <ul style="list-style-type: none"> •Building/ Construction •Manipulating •Sorting/ Classifying •Measuring •Comparing •Counting •Balancing <p>Arts</p> <ul style="list-style-type: none"> •Art •Music •Dance •Language and Literacy •Signs/ Symbols 	<ul style="list-style-type: none"> •Functional/ Physical Play •Constructive Play •Dramatic Play •Game with Rules •No Play 	<ul style="list-style-type: none"> •Solitary Play •Parallel Play •Couple •Group Play •Playing with an Adult •Conflict •Other 	<ul style="list-style-type: none"> •Touch •Sight •Sound •Smell •Taste 	<ul style="list-style-type: none"> •Self •One Child •Multiple Children •Adult •Child and Adult •None

The researchers divided the 2 hours and 48 minutes of video into 56 equal 3-minute time frames following the momentary time sampling technique. From the last 15 seconds of recordings of each interval, the most observed behavior of each child was coded across all six categories: Existing Play Settings, STEAM Learning Behaviors, Types of Play Behavior, Social Play Behavior, Sensory Play Behavior, and Conversation (see Table 1). For example, if ten children were in a particular area, the researcher would pause the video at the 15-second mark and code the predominant behavior observed for each child. If a child moved in and out of an area, the researcher recorded the dominant behavior during the time the child was present. Moreover, if a child engaged in multiple behaviors within a category, like dramatic play and physical play at the same time, the behavior with the longest duration or highest frequency was recorded. If no behavior is observed in any of the six categories, the coding is recorded as blank. The video could be paused, zoomed in, or rewound if necessary.

In the coding scheme, the same behavior (e.g., building) might have been sampled multiple times for each child. We did not control for this “double coding,” as the aim

was to gauge the relative frequencies of various STEAM-supportive play and learning behaviors across the outdoor play settings. While individual child-level frequencies were not feasible to register, children typically engaged in the same behavior for the entire 15-second segment. In cases where multiple behaviors occurred within the segment, the predominant behavior was apparent due to differences in duration. When behavior was too mixed or a child was in the area for too short a time to determine an evident predominant behavior, the behavior was labeled as “uncodable.”

Intercoder Reliability

Two pre-trained research assistants coded the video data. Each researcher coded 5 minutes of video data from a target area. Afterward, similarities, differences, and potential coding challenges were discussed. The protocol was then updated with suggestions for handling difficulties and ambiguities. When a difficulty arose during coding, the research team reviewed the video together to decide how to code the behavior. The degree of agreement is quantified by kappa, which is 0.97.

Data Analysis and Results

The hypothesis to be tested was that the WS Zoo School's outdoor play and learning environment, designed with affordance-rich landscape elements, is associated with increased occurrences of STEAM-related behaviors and STEAM learning. In other words, this study aimed to establish a relationship between 18 existing outdoor play and learning settings and the associated STEAM-supportive activities of preschoolers. Through video observation of children in the outdoor play areas of the WS Zoo School, this study documented a positive relationship between affordance-rich outdoor play settings and the frequency of STEAM-related behaviors exhibited by children. While a positive association was observed in most settings, the level of engagement varied, with some areas showing limited STEAM-related behaviors. Two key findings structured the analysis presented in the following sections: (a) landscape elements in existing natural play settings that shape the type and frequency of children's STEAM learning behaviors; and (b) temporal patterns illustrating how STEAM-supportive settings influence the duration and complexity of children's play, social interactions, sensory explorations, and conversational exchanges.

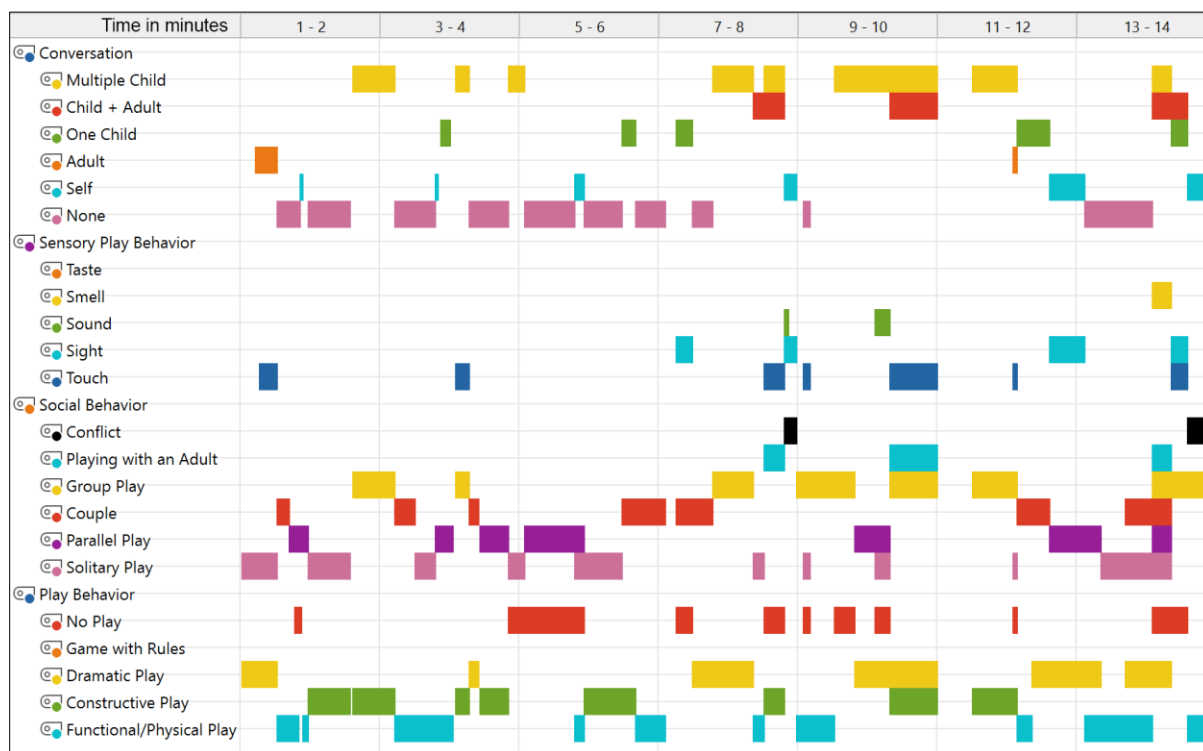
Temporal Patterns of Children's Behavior During Outdoor Play Time

The WS Zoo School video analysis revealed that children's play in existing outdoor play settings is supported by both the natural and constructed surroundings. Nature delivered far more variables in the form of play props and open-ended play opportunities than traditional childcare outdoor environments with large areas of safety surfaces and fixed equipment. The WS Zoo School's nature-based and diverse early childhood learning environment let children experience the changing seasons, see the life cycles of plants, animals, and insects, and explore and play with natural materials.

The temporal pattern analysis data (Table 2) for the WS Zoo School highlights distinct patterns of children's behaviors during outdoor play time across diverse play settings. Group play emerges as the most visible Social Play Behavior,

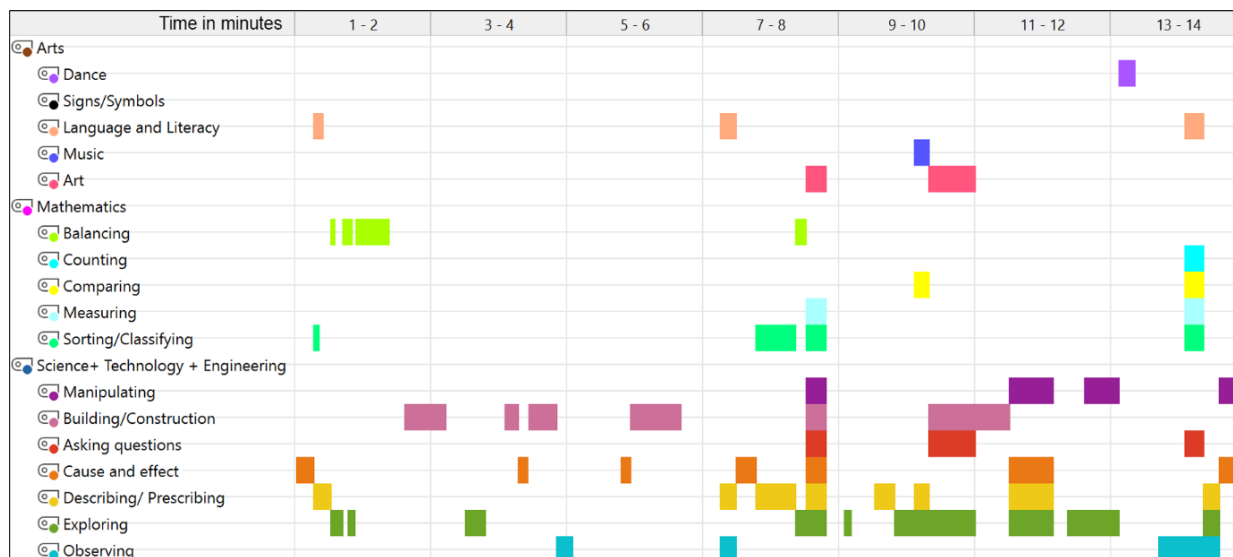
consistently observed across the timeline, which indicates its prominence in fostering social interactions among children. Similarly, Conversational interactions, primarily involving multiple children, are frequently noted, underscoring the social nature of the play settings. Solitary play also appears less frequently compared to group and parallel play, indicating a stronger inclination towards collaborative social play in these settings. Sensory Play Behaviors, specifically those related to taste and smell, are less visible, suggesting these sensory experiences are less prevalent or less emphasized during observed play periods.

Table 2. Temporal patterns of children's play behavior types, social play, sensory play, and conversation behavior during outdoor play time in existing play settings



The analysis of the temporal distribution of STEAM behaviors in children during outdoor play, as detailed in Table 3, underscores prominent and sporadic activities within STEAM disciplines. Mathematics behaviors, particularly balancing, sorting and comparing, are the most consistently observed, suggesting these skills are frequently explored and reinforced in outdoor play settings. In contrast, arts-related behaviors such as dance and music are notably less frequent, indicating that these activities may not be as integrally facilitated or may occur less naturally in these settings. Among Science + Technology + Engineering behaviors, building/ construction, cause and effect, exploring and describing activities emerge as significantly engaged, reflecting the children's interaction with materials and structures conducive to understanding physical and spatial concepts. This pattern reveals that the available affordances of the WS Zoo School make it a STEAM-supportive outdoor play setting.

Table 3. Temporal patterns of children's STEAM learning behaviors during outdoor play time in existing settings



Play Settings and Their Relation to STEAM Learning Behaviors

Undoubtedly, this research, while analyzing existing play settings at the WS Zoo School, is not just about the presence of natural elements but how they are integrated into the environment. The design of pathways, the proximity of different elements to each other, and overall accessibility significantly impacted how children interact with the natural outdoor environment and, consequently, their STEAM learning experiences. In such a setting thoughtfully equipped with selected materials and abundant exploration opportunities, children will naturally express their curiosity and questions verbally and through actions (Worth & Grollman, 2003). In the WS Zoo School setting, children can self-select areas in which to play, with whom they want to play, and the types of play activities in which they wish to engage.

It is observed that children frequently engage in STEAM-related activities in affordance-rich, diverse natural settings. They actively explore and manipulate objects, closely examining the characteristics of texture, size, or material. These properties influence how children use these items; for instance, they use large, sturdy tree logs to construct climbing structures and softer materials (e.g., a piece of cloth) to cover their faces and act like ghosts.

Table 4 shows a comprehensive table of the frequencies of STEAM learning behaviors across the various play settings, illustrating a notable variance in engagement levels. Video data reveals that most STEAM learning behaviors are visible in places with loose parts play materials, suggesting that child interactions with diverse natural materials promote STEAM learning. Storage facilities specially designed with multiple affordances are another setting where we identified many STEAM-related activities. Large blocks and construction areas on the site offer

opportunities for children to interact with peers and practice socialization skills. The areas help children to be more creative. Similarly, areas with a large number of child-friendly plants demonstrate substantial engagement, aligning with their potential to foster observational capacity and exploration skills.

Conversely, acoustic play settings, art areas, and pretend and performance areas show moderate levels of STEAM activity, suggesting smaller but specific contributions to STEAM learning. Notably, in areas with the presence of moveable play structures and with diverse topography and landforms, children display a greater engagement with STEAM learning activities than in the settings with fixed play structures, pointing to their limited direct efficacy in promoting observable STEAM behaviors. These insights underscore the need for diverse play settings to cultivate varied STEAM learning experiences and highlight the importance of designing educational play areas that enhance settings conducive to active and multifaceted learning.

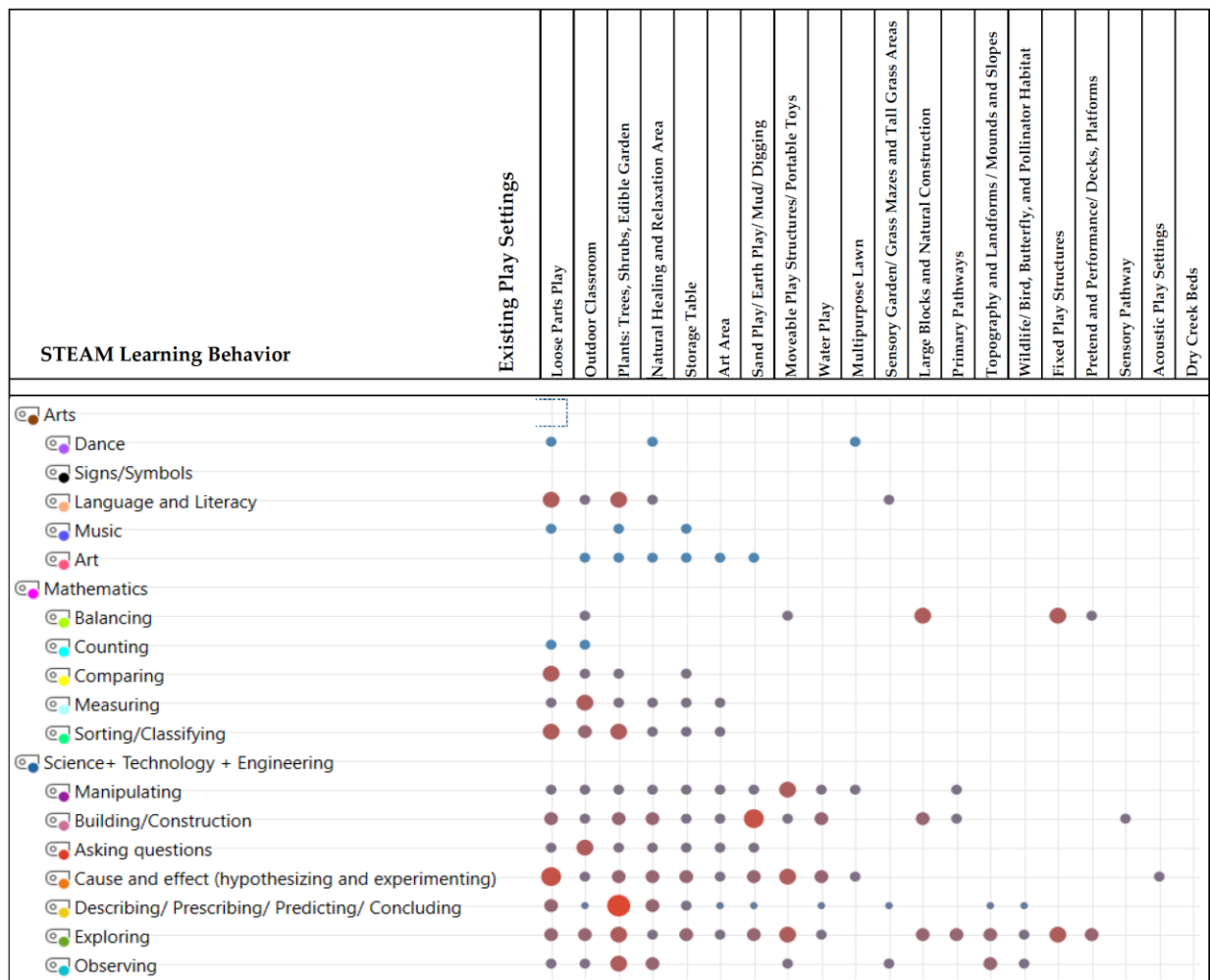
Table 4. Frequencies of STEAM learning behaviors across diverse play settings

Existing Play Settings	Frequencies of STEAM Learning Behaviors
Acoustic Play Settings	Low frequency (blue bar)
Art Area	Low frequency (blue bar)
Dry Creek Beds	Low frequency (green bar)
Fixed Play Structures	Low frequency (orange bar)
Large Blocks and Natural Construction	Low frequency (red bar)
Loose Parts Play	High frequency (red bar)
Moveable Play Structures/ Portable Toys and Equipment	High frequency (green bar)
Multipurpose Lawn	Low frequency (blue bar)
Natural Healing and Relaxation Area	Low frequency (light blue bar)
Outdoor Classroom	Low frequency (light green bar)
Plants: Trees, Shrubs, Edible Garden	High frequency (orange bar)
Pretend and Performance/ Decks, Platforms, and Stages	Low frequency (red bar)
Primary Pathways	Low frequency (red bar)
Sand Play/ Earth Play/ Mud/ Digging	Low frequency (green bar)
Sensory Garden/ Grass Mazes and Tall Grass Areas	Low frequency (blue bar)
Sensory Pathway	Low frequency (light blue bar)
Storage Table	Low frequency (light green bar)
Topography and Landforms / Mounds and Slopes	Low frequency (orange bar)
Water Play	Low frequency (red bar)
Wildlife/ Bird, Butterfly, and Pollinator Habitat	Low frequency (red bar)

Table 5 illustrates the relationship between children's STEAM learning behaviors and associated play settings, revealing distinct patterns of engagement across various environments. Mathematics activities, particularly comparing, measuring, and sorting, are prevalent in both structured and unstructured environments, such as outdoor classroom areas and loose parts play areas with the availability of plants, while balancing activities are visible only in large blocks and natural construction areas, suggesting these settings are conducive to quantitative explorations. In the realm of Science + Technology + Engineering, building/construction, and cause and effect activities are notably frequent in areas designed for manipulative play, such as sand and water play, highlighting the importance of tangible, hands-on experiences in fostering engineering skills. Language and literacy activities within the Arts category are primarily observed in the outdoor classroom, loose parts play

areas, and areas with plants and sensory gardens, indicating these settings support narrative and communicative developments. Conversely, behaviors such as exploration and observation are predominantly seen in nature-focused settings like plants and the natural healing and relaxation area, underscoring the role of natural environments in promoting inquiry-based learning.

Table 5. Mapping STEAM learning behaviors across diverse outdoor play settings



In Table 5, the sizes of the dots reflect the frequency of each STEAM learning behavior identified in each setting, with each frequency count represented by different colored dots. For instance, larger red dots indicate the maximum frequency, and in Science + Technology + Engineering coding, describing/ prescribing/ predicting/ concluding behaviors are at the maximum frequency in the plants: trees, shrubs, edible garden environment.

Mapping Interaction and Play Dynamics across Diverse Outdoor Learning Environments

This case study site (Figure 4) has spatial arrangements that are aesthetically pleasing, functional, and conducive to learning. Different activities like sand play, water play, or multipurpose lawn areas contribute to a diverse range of play and learning experiences. For instance, a well-placed water and sand play area encourages more interactive and exploratory learning. A mix of formal and informal learning and enjoyable experiences in these naturalized settings was most closely linked with fostering environmentally responsible behaviors in children.

Figure 4. Affordance-rich outdoor learning environments of the Will Smith Zoo School



In Table 6, the size of the dots reflects the frequency of each behavior identified in each setting, with each frequency count represented by different colored dots. Larger red dots indicate the maximum frequency; for instance, the most frequent Conversation behavior is “none” in the moveable play structures/portable toys environment; in Social Behavior coding, “solitary play,” has the maximum frequency in loose parts play; in Play Behavior Type coding, “no play” has the maximum frequency in the natural healing and relaxation area, and “dramatic play” shows the most frequent behavior in loose parts play areas.

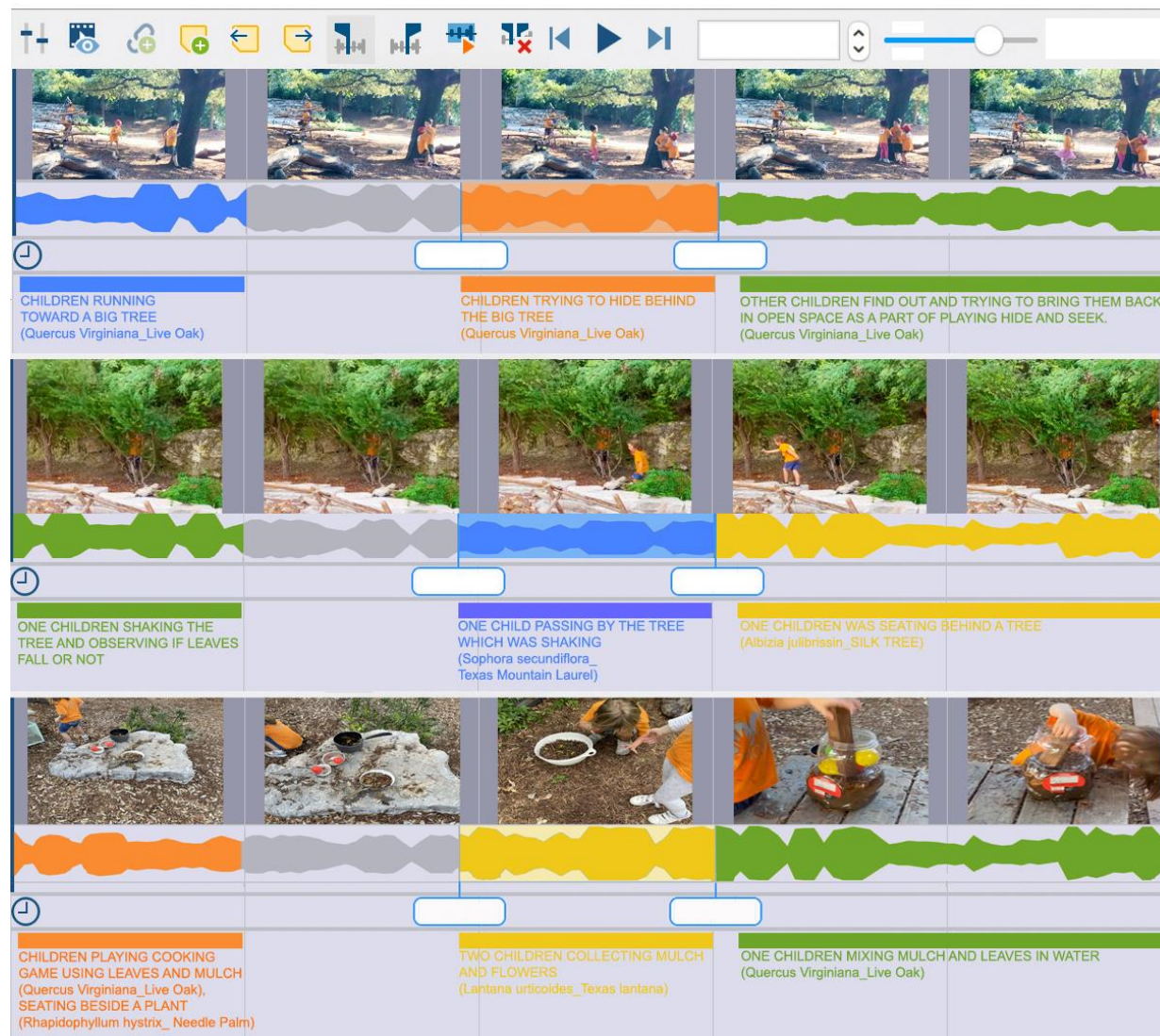
Notably, group play, couple play, and parallel play behaviors, highlighted through consistent presence across settings like large blocks and natural construction areas and places with moveable play structures/portable toys, suggest these areas are central hubs for collaborative and social interactions. Sensory behaviors associated with touch are predominantly observed in settings such as sand play and water play, indicating these environments are particularly conducive to tactile engagements. In contrast, dramatic play exhibits a strong presence in settings *not* designed for imaginative activities but rather in areas with loose parts of play materials. On the other hand, solitary play is less frequent, occurring sporadically across most settings but with less consistency than group play, indicating a broader preference or opportunity for social play in these environments. According to Smith Roley et al. (2015), this pattern underscores the role of unstructured and sensory-rich play settings in facilitating specific types of interactions and developmental behaviors among children.

Records of the Use of Plants and Plant Materials in Children’s Play Activities

A large number of play and learning opportunities provided by plants and plant materials in this context are revealed. Further, video analysis reveals how children interact with the existing trees on this site and also reveals their favorite activities around and with trees. For instance, Figure 5 illustrates that existing plants including *Quercus virginiana* (Live Oak), *Sophora secundiflora* (Texas Mountain Laurel), *Albizia julibrissin* (Silk Tree), *Rhaphidophyllum hystrix* (Needle Palm), and *Lantana corticoids* (Texas Lantana) are used by children in their play and influence their STEAM activities.

The blend of thoughtfully designed play areas and abundant plants and plant materials enables children to express their thoughts in innovative ways. In this study, we found that children's access to a variety of natural materials allows them to develop a wide range of skills. Children engaged in critical thinking as they purposefully selected plant materials to serve as props in their pretend play. The plant-derived loose parts provided by a well-designed planting palette ensured that children had rich and diverse plant resources as play props, “affording” them to engage in free play. In the well-designed outdoor settings of the WS Zoo School, children can convert simple parts of plants into objects with several functionalities.

Figure 4. Diverse plants and plant materials and associated children's behavior



Discussion

Well-designed play areas incorporate diverse natural elements like trees, shrubs, plants, soil, sand, water, leaves, flowers, seeds, and small sticks. These features stimulate children's senses and broaden their range of play activities (Frost, 2015). For many children, a wild natural environment may appear intimidating. However, at the WS Zoo School, the natural setting is structured and accessible, enabling children to feel secure while engaged in diverse play settings to explore and understand their surroundings.

This research underscores the pivotal role of affordance-rich outdoor play environments in fostering STEAM learning behaviors among preschool children. Through the in-depth analysis of children's interactions within the WS Zoo School's

naturalized play settings, the findings of this research suggest that well-designed outdoor environments with diverse natural landscape elements are associated with increased occurrences of behaviors indicative of STEAM learning. The findings also reveal that children engage in a wide array of STEAM learning behaviors when provided with environments that offer open-ended and exploratory play opportunities. The study demonstrates that natural materials, such as sand, water, plants, and loose parts, provide affordances for children's inquiry-based learning and social interactions, thereby creating a dynamic and inclusive learning environment that transcends traditional play structures. These elements encourage children to engage in critical thinking and problem-solving and foster their creativity and social collaboration.

Moreover, the temporal analysis of children's behavior patterns highlights the importance of diverse play settings in promoting specific STEAM learning activities. Settings that incorporate moveable play structures, varied topography, and natural elements like plants and water are particularly conducive to activities such as building, sorting, comparing, and exploring—core components of STEAM education. By identifying which sub-sets of the environment are associated with particular behaviors, this research provides actionable insights for designing outdoor spaces that support early childhood STEAM learning. The findings advocate for a shift in the design of childcare outdoor spaces towards more diverse, naturalized environments that prioritize children's developmental needs through the provision of rich, exploratory play opportunities.

The findings from this study aligned with several previous studies that emphasize the critical role of natural settings and landscape elements in outdoor learning environments (Cetken-Aktas & Sevimli-Celik, 2023; Herrington & Studtmann, 1998; van Dijk-Wesselius et al., 2022; Wight et al., 2016). Similar to this research, Cetken-Aktas and Sevimli-Celik (2023) highlight that an environment rich in natural elements, such as trees, water, and varied topography, significantly encourages creative, collaborative, and inquiry-based play, which are essential components of STEAM learning. Further, the present study concludes that movable and flexible natural play settings are more effective in promoting diverse STEAM activities, echoing findings from the Wight et al. (2016) study, which observed that such environments foster environmental responsibility behaviors through hands-on interaction. Furthermore, both the results of the present study and those of Herrington and Studtmann (1998) agree that landscape interventions in outdoor play areas can enhance not just physical development but also cognitive, social, and emotional growth, providing a more holistic developmental experience for children.

Opportunities to interact with diverse nature play settings are beneficial for children in many different ways and empirical evidence suggests that nature connections are directly related to multiple developmental domains including cognitive development. High-quality, affordance-rich outdoor learning environments can ensure quality outdoor times for children. It is critical to understand how intentional use of landscape elements in outdoor learning environment design can facilitate STEAM learning in a childcare setting. This research provides insights for designers,

early childhood educators, researchers, and policymakers about innovative ways to design affordance-rich play settings to improve nature interactions in an outdoor environment for children in a childcare/preschool setting where children spend a significant portion of the day.

Limitations, Delimitations, and Future Research

The momentary time sampling data analysis method is limited to recording events that occur within a predetermined period and is subject to clock monitoring. However, this technique is particularly effective in providing an objective record of children's behavior and indicating whether concerns require intervention in the specified play settings. Momentary time sampling is a relatively straightforward method for video data analysis, as it estimates overall behavior rather than the documentation of each occurrence (Miller, 2010). In this research, the momentary time sample method is used to capture behaviors at specific moments in time rather than continuous actions. It may underestimate a child's behavior, as the children may engage in a behavior throughout an interval but cease just before the end of the interval. However, this study focused on identifying patterns and relationships between nature-based outdoor play environments and STEAM-related behaviors, which is inferred from the observed frequency and variety of STEAM-related behaviors rather than being directly measured through standardized assessment tools. Future studies should employ longitudinal or experimental designs to quantify the impact of such environments on STEAM learning outcomes. To mitigate this limitation, researchers also perform frequent reliability checks between coders to ensure consistency in interpreting behaviors, particularly in ambiguous scenarios.

Although this study was conducted at a single case study site, the WS Zoo School, the insights gained offer a foundation for understanding children's interactions in play settings and can be adapted to explore other environments that foster STEAM learning activities.

This study focused on specific landscape elements and outdoor play settings, with a particular emphasis on preschool children aged 3-5 years. By narrowing the scope to this age group, the study provides a detailed understanding of their unique interaction dynamics within naturalized outdoor environments. This targeted approach allows for an in-depth exploration of how these settings support STEAM learning behaviors, offering valuable insights that might be less apparent in broader studies. The exclusion of indoor and more structured learning environments enables a concentrated examination of the benefits provided by nature-based outdoor play areas. Future studies should compare different educational settings, further illuminating the positive impact of outdoor environments on STEAM learning behaviors. Most importantly, intervention studies that implement and evaluate changes in play settings based on empirical findings could validate the effectiveness of specific design elements in enhancing the STEAM learning activities in an outdoor play area.

Conclusions

The design of the outdoor learning environment at the WS Zoo School influences

the richness and diversity of children's play and STEAM learning activities. Play and learning occur more readily in spaces that offer various possibilities, known as affordances, which are the potential activities a space allows (Gibson, 2014; Morgenthaler et al., 2024; Sharma-Brymer et al., 2018). The design, size, landscape, and elements within this case study site, being both natural and man-made, shape these affordances. For instance, video data shows that children identified a concrete area as perfect for bouncing a ball, while a grassy hill was used for rolling down. A child's perspective on these affordances, such as viewing a climbable tree as an exciting challenge rather than a hazard, often differs from an adult's more cautious viewpoint. It is crucial for those who provide play opportunities to recognize and consider the different ways children might engage with these affordances beyond current or adult use (Tunncliffe & Kennedy, 2022). The more varied and intricate an affordance is, the more action possibilities it presents to children.

This study highlighted that children's play in this well-designed, affordance-rich natural setting was rich in focused and imaginative social interactions. Playing in such natural surroundings also increases children's curiosity about their environment, leading to more vivid recounts of their experiences (Elkind, 2007). In these spaces, children actively shape their surroundings with intent and become deeply engrossed in their activities. These observations suggest that the intentional design of an outdoor environment with diverse landscape elements can facilitate behaviors that are advantageous for early STEAM education (e.g., creativity, social interaction, and detailed observation).

Outdoor learning environments can influence STEAM education with intentional design elements. Those elements can offer STEAM learning affordances and create informal environments crucial to STEAM education, such as a diverse range of natural resources that children can use in their play, fostering creativity, social interaction, and complex activities like construction projects. Traditional playgrounds are not as effective in encouraging STEM-related play (Weiser, 2022). In sum, this case study serves as an exemplary illustration of how unstructured, affordance-rich natural environments can provide a wide range of STEAM learning opportunities while increasing the flexibility and adaptability of settings for children's active engagement.

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