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Published in:
CHI '25

DOI:
10.1145/3706598.3713303

2025

Document Version:
Publisher's PDF, also known as Version of record

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A Study of Digital Play Installations from a Nature Play Perspective

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Abstract

While digital play installations for outdoor use are becoming more common, little work has been done on how such technology shapes play in nature-rich environments. We performed a study of children's self-directed play with access to nature as well as digital installations. Our findings show that play with nature materials and digital installations emerged in different ways. Most notably, imaginative play was observed emerging in close interaction with nature, while the digital installations mostly inspired rule-based play. Furthermore, engagement with digital installations typically involved an active exploration phase which was not observed with nature materials. Nature materials instead engaged the children's senses more immediately, and often offered opportunities for collection and consumption, paving way for fluent play activities roaming large areas. We argue that these differences motivate rethinking the design of digital installations for play in nature and suggest guidelines to this purpose.

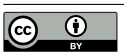
CCS Concepts

• ; • **Human-centered computing** → Interaction design; Empirical studies in interaction design;

Keywords

digital outdoor play, open-ended play, restoration, children´s play, nature, nature-rich settings, landscape architecture, nature play

ACM Reference Format:
Annika Waern, Fredrika Mårtensson, Jon Back, Anna Litsmark, and Eva-Lotta Sallnäs Pysander. 2025. Digital Play in Nature: A Study of Digital Play Installations from a Nature Play Perspective. In *CHI Conference on Human Factors in Computing Systems (CHI '25), April 26–May 01, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 19 pages. https://doi.org/10.1145/3706598.3713303



CHI '25, Yokohama, Japan

ACM ISBN 979-8-4007-1394-1/2025/04
https://doi.org/10.1145/3706598.3713303

1 Introduction

Recently, we have seen a move within Human-Computer Interaction (HCI) towards exploring ways to support children's outdoor play, sometimes with the idea of enriching their nature experiences. Several reasons underlie the trend; in particular, the global trend of children being less and less active outdoors [82] despite the benefits of outdoor play on children's physiological well-being, joy and learning. Environmental psychology increasingly supports the idea that having access to nature[1] in play settings is beneficial for children's psychological, physiological and cognitive development [14, 52, 79]. Clayton et al. [15] further highlight how the increased marginalization of nature experiences in all ages has deleterious consequences for people's emotional, attitudinal, and behavioural relations to nature and biodiversity, issues that inspire explorations into Nature HCI [31]. Empirical research indicates that children's early experiences of being in nature helps foster a positive and nurturing affinity to nature in adults [13]. Cumbo and Pedersen [18] propose that this is a particularly important opportunity for digital technology in nature settings, "*to support the child-directed nature-play experiences known to instill a value for nature and motivate environmental stewardship later in life*".

Research on digital support for children's play in nature has predominantly focussed on finding ways to make digital technology relevant for enriching children's play in nature-rich settings. For example, a design workshop with children [19] explored motivations for outdoor play and how these could be supported by digital play tools, uncovering motivations such as placemaking, connecting to living creatures, and challenging oneself in explorative experiences. A design ethnography [80] came further in uncovering the rich palette of play that emerges in nature, and emphasised the social and bricolage nature of outdoor play, suggesting the design of play technology that can be used together with materials found in the space. At the same time, environmental psychology research has

[1] In this article, 'access to nature 'refers to having access to greenery as well as natural landscape formations.

uncovered how children´s play evolves in relation to the flowing terrain [53, 54], and is characterised by flux and transformation [50, 79] in how children tend to engage in swift and playful movements [42]. These aspects have not previously been taken into consideration in work on digital technology for children's outdoor play. It has been shown that these forms of play appear to have both health benefits [79] and promote pro-social behaviour [38, 52]. Such benefits are at risk, if the ways in which children already play in nature-rich settings are not fully considered in the design of digital play tools.

This article presents a study on how play evolves when digital installations are present in nature-rich settings. We had the unique opportunity to study children's self-directed play[2] in nature-rich locations with access also to digital installations. In contrast with previous studies, this allowed us to shift focus from the installations as such, to instead study how the children's play activities emerged in relation to the rich palette of materials present. Our study takes into consideration all of digital installations, nature materials, landscape features, and non-digital installations, with the aim to uncover similarities and differences between how children engage with digital installations and with other materials present in nature-rich settings. This also means that we do not make any a priori distinction between digital play and nature-based play. Rather, we make note of which materials are recruited into play to uncover how the different materials inspire play engagement.

To shift focus from studying the play installations in isolation, we adopted a method from landscape architecture studies, to elicit how children engage in *situated play episodes* [51]. A situated play episode is an identifiable unit in children's play activity that can undergo continuous change, with the children moving between different sites, children entering and leaving the activity, and the children modifying their narrative and overall play agreement [7] as play evolves. This concept was developed to capture the open-ended type of play that is common in outdoor settings [51]. The approach allows us to move away from placing focus on singular materials or installations, to instead study how play emerges in interaction with the place and the materials at hand.

The play episodes analysed in this study were collected during four observation sessions in which groups of children were playing freely in four different settings. Two of the settings included digital installations, and the other two were a park with regular playground installations, and a forest area with no artificial play equipment. Through a combined analysis of qualitative data sources (video recordings, observation notes and interviews) we elicited 30 situated play episodes over all four areas. This article is based on a qualitative analysis of this material, to answer the following research questions:

- Are there differences between how children engage with digital installations and nature materials in outdoor play, and if so, what are the possible reasons for these?
- Based on any observed differences, what challenges and opportunities do we see for designing digital outdoor play installations for nature-rich settings?

Our findings show that play with nature materials versus digital installations emerged in *different* ways. Engagement with digital installations typically involved an active exploration phase, which was rare to non-existent with other materials, and which strongly influenced the subsequent play engagement. With nature materials on the other hand, sensory exploration was playful in and of itself. Second, we did not observe imaginative play emerging in the engagement with digital installations, that rather inspired rule-based play. Finally, the ways in which many nature materials are collectable, consumable and malleable strongly influenced children's play engagement with them, and contributed to their attractiveness. We argue that in order to ensure that the psychological and health benefits of play in nature, this motivates rethinking the design of digital installations for nature-rich settings and suggest guidelines to this purpose.

[2]Self-directed play refers to unorganized play that may or may not be supervised [1].

2 Background

2.1 Children's Outdoor Play

Studies of children's outdoor play have begun to uncover how the ambiguity and constantly changing characteristics of biological, geological and seasonal processes present outdoors [69] are formative for children´s play. Nature features also trigger pro-social behaviour [38, 52]. When there is an abundance of nature materials [56] it forms a common ground making it more likely that children of different genders, ages, competences and interests, can negotiate and play together [82]. An example is how an intervention [34] in which plants were added to an otherwise barren environment led to an increase in imaginative play and socializing. Nature's restorative effects has also been shown to be supportive of a general capability to handle stress and life challenges and higher achievements in school [79]. Vegetation and other nature features tend to fascinate children and instil sense of wonder [41, 43], and in their play and social interactions, nature features make play more flexible, diverse and open-ended [51]. Play in nature is characterised by flux and transformation [50, 79]: children tend to engage in swift and playful movements [42], experimenting with materials in ways that extend their functions. For all of these reasons, a general decrease in outdoor play [16] and unequal access to green play settings [72] has increasingly been regarded as a threat to children´s overall health and development [20].

These observations underlie recent approaches to both playground design [26] and incorporation of digital materials in outdoor settings [65]. However, we still know little about how digital installations interact with nature features in green play settings.

2.2 Digital Outdoor Play

As traditional outdoor play is considered challenged by digital play in children's lives [35], many scholars have considered ways in which digital technology could be designed to enrich outdoor play and possibly make the outdoor environment more attractive to children. Previous design experiments include fixed outdoor installations [3, 8, 23, 60, 63, 73, 75] but also loose play artefacts [35, 70] and collections of artefacts or apps that work as modular building blocks [22, 24, 49, 71]. As with traditional playground installations, the purpose has often been to foster physical activity (e.g. [49, 55, 78]), but there are also efforts to support more versatile and creative play [3, 8, 22, 23, 60, 70, 73]. Multiple authors (see e.g. [11, 35, 70, 75]) propose that digital play artefacts should provide

open-ended feedback as this can inspire exploration and creativity, rather than e.g. implement games with fixed scores. Several also recommend providing adaptable or re-programmable functions [2, 5]. Revisiting multiple experiences of designing for outdoor play, Fails and Jones [25] have suggested design recommendations for the design of digital tools for play in nature. Their recommendations include using narratives to stimulate the children's interest and supporting exploration in open, generative and creative ways. However, they also consider outdoor play activities to be activities that have adults present and urge designers to consider the need to keep children safe, recommendations that can be challenged from an environmental psychology perspective [68].

Child-computer interaction research has also uncovered how digital play artefacts can be designed to foster long-lasting and creative play engagements. Inspired by toy research [37], De Valk et al. [75] developed design principles for open-ended feedback to foster open-ended play which consists of three phases. The first phase is when the play artefact attracts the children's attention and invites them to play with it. When the children begin interaction with the artefact, a phase of *exploration* follows, eventually moving into a phase of *immersive play*, in which the children play in an intense and focussed way with the artefact and each other. De Valk et al considers it desirable that immersive play should also, now and then, shift back to exploration, when the children detect new usages for the artefact, as this can encourage long-lasting creative play behaviours. Back et al. [7] suggest that such shifts do not just depend on discovering new functionalities, but also emerge through social negotiations and transgressive behaviour among the children. In relation to outdoor digital play installations, Back et al. [8] furthermore suggest that it might be more appropriate to study the capacity for designs to foster *recurring* play, as children seldom get the opportunity to play for very long periods of time outdoors, but on the other hand are likely to visit the same outdoor settings recurrently.

2.3 Bridging Concepts when Approaching Play from Interaction Design and Landscape Studies

The reported project takes an interdisciplinary approach to the study of outdoor play, bridging interaction design, environmental psychology and landscape architecture research. While the disciplines have a common foundation in behavioural science and share many theories and concepts, these are slightly differently applied. In this section we bring forth similarities and differences in conceptualisations of *affordances* and *open play* in the different fields, in an effort to support joint language [21]. In this article, these concepts are used with a clear reference to the respective fields when necessary. Finally, we discuss the play typology chosen for analysis in this study.

The concept of affordances has a prominent position in discussions of technology design as well as in studies of children´s outdoor environment. The concept originates in Gibson's proposal that our way of perceiving the world is grounded in a preparedness for moving around and making use of our surroundings [30, 33]. Through this preparedness, we acknowledge distinct functional properties in the environment depending on our constitution and capacity, e.g. observing various features as being climbable, slideable, swingable, and so forth. Within playground research, multiple authors have discussed how different affordances in the physical environment [17, 32, 47, 62] affect children's play. Studies in *landscape research* and *environmental psychology* document children´s playful interaction and exploration of affordances outdoors, focussing on nature materials and various features in the environment including playground gear [26, 27, 47, 50]. It should be noted that seasonal variation and weather conditions also provide affordances for play [67].

In *interaction design*, focus has more commonly been placed on how affordances can be *designed* [46], through a deliberate process that determines which functionalities an artefact should offer and how these should be communicated to users. Norman [57] first made use of the concept of affordances to describe such design choices. The relational perspective on affordances as the individual's orientation to their environment tends to be less in focus in this work. However, designed artefacts mostly offer both affordances that have been deliberately designed, and such that emerge anyways e.g. from unintended code interactions (bugs), from physical properties of an artefact, and from the social and physical environment in which the artefact is situated.

Human beings are, by both nature and previous exposure, well attuned to nature affordances and experience little challenge in relating to them. Designed artefacts offer less of such affordances, while instead offering modes of use that are uncommon or unique. Finding ways of communicating digital affordances as clearly and easily as possible has been a central consideration in design [29], even though the goal of offering unambiguous and clear affordances has become increasingly challenged as it also can restrict the possible usage options [61]. Proposals to capitalize on ambiguity in design [28] and the previously mentioned strategy to design for open-ended play [75] challenge the predominant approach of providing affordances with clearly delimited usages.

Open-ended play is another important consideration across the research fields, again a concept used slightly differently. In interaction design, the term is primarily used in contrast to game design [9, 60], which steers interaction towards limited goals (predominantly winning) and thus limits the opportunities for participants to re-invent their ongoing play activity. Open-ended play then emerges from engaging with open-ended interaction designs that do not have a set purpose or win condition, making them open for appropriation e.g. so that game goals can be socially negotiated [7]. In literature on children´s outdoor play environments, open-ended play refers to how play is more flexible and open for change in outdoors settings [50] than in other settings, and argues that activities of sensory exploration and playful use of affordances lie at the core of such play. As discussed in the background these are also forms of engagement that are associated with restorative play [42].

2.4 An Outdoor Play Typology

A plethora of typologies for children´s play exist [81], most developed for the purpose of studying children's play development. In our work, we made use of the Tool for Observing Play Outdoors (TOPO) [48], with slight adaptations. This typology is grounded in established categorisations of children's play [64] but tailored for

Table 1: Overview of the play types used in the presented study, based on TOPO [48]

Play types
Movement Play: Gross Movement, Fine Movement, Rough and Tumble, Vestibular
Explorative Play: Sensory Exploration, Active Exploration, Construction
Imaginative Play: Symbolic, SocioDramatic, Fantastic
Play with Rules: Organic, Conventional
Expressive Play: Performance, Artistic, Language
Nature Play: Observe, Care, Harm
Restorative play: Rest, Retreat
Other

children´s play behaviour outdoors with access to nature elements. TOPO divides children's play into nine categories: Movement, Explorative, Imaginative, Play with rules, Expressive, Restorative, Digital, Bioplay and Restorative. Each category of play is further divided into sub-categories.

The categories used in this study were adapted from TOPO with two modifications. Digital play was omitted as a category of its own, as the digital installations (and actually, some other digital materials) were instead considered play materials. For the same reason, Bioplay was named nature play and categorised not by what kind of biological material was used, but by what ways in which children the children engaged with the materials. The resulting eight categories are shown in Table 1. In addition to these classifications, we noted down which materials the children made use of in the play episode (this is further discussed in the method section).

In the analysis conducted for this paper, that builds on a combination of observer notes, video analysis and interview transcripts, a selection of these categories emerged as the most salient forms of engagement, and are therefore described here in more detail.

Explorative play is an important factor in children's cognitive and social development [77] and a common element in play. TOPO distinguishes between Sensory exploration, in which the exploration is mainly directed towards sensory experiences, Active exploration which is when "a child attentively explores an object or the environment in an active and attentive manner, and Construction (here discussed as Constructive play) which is when the children reshape materials constructing something else out of them. *Sensory Exploration* is a fundamental aspect of children's play, integrated in their very first playful interactions with the world around them [59, 64] and characteristic for a lot of play outdoors where children attentively explore the surroundings. While Movement play is classified separately in TOPO, both *Gross Motor* play and *Vestibular Play* also include aspects of sensory exploration through the proprioceptive senses [45]. The concept of *Active Exploration* originates in studies of science centre installations, where it is typically directed towards figuring out the function of a science centre exhibit, but active exploration is also possible in nature settings and could e.g. involve manipulating a flow of water to change its course. *Constructive Play* is often associated with materials that are loose and malleable such as sand, toys, sticks, boards, and tools. Particular for constructive play is children's ideas dominating the materials, which is recruited in order to *construct* something out of them. This type of play tends to leave traces of reshaped material. Sandcastles and elaborate huts are classical examples, but commonly the result of children´s creative activity can be very modest constructions [44].

Play with rules is when the children collectively adopt a set of game-like rules to structure their activity. This can sometimes include a 'win' condition. The resulting activity becomes similar to a game, that can be collaborative or competitive, or both. Rule-based play is considered *Conventional rule-based* when the game is known by all of the children and the ruleset is more or less strictly adhered to. It is considered *Organic rule-based* when the children do not adopt a pre-existing game but invent their own, often underspecified, set of rules. Typically, organic play activities are constantly re-negotiated, subject to frequent changes in rules, goals, and roles [7].

Imaginative play emerges when children engage their fantasy in different ways [48]. Typically, this involves re-signifying something, including enacting roles, designating a place to be their home, or re-signifying materials to represent something else in the play activity (e.g. a stick becomes a horse). The three subcategories in TOPO (*Symbolic*, *Socio-dramatic* and *Fantastic*) are based on how literature on children's play development see these as progressively more advanced forms of imaginative play. In our study, it turned out to be difficult to draw clear lines between them, why only the top category was used in the analysis.

In addition to the TOPO categories, our analysis also makes note of instances of **work play** [8]. This concept has been used to describe a form of play that seems to be common in social play with digital outdoor installations. In this form of play, the children are intensely engaged with creating maximum result from the digital feedback, often under the guidance of a child acting as leader. While work play seems particularly common with digital installations, it emerges also in play in nature as children confronted with the challenges of nature children will sometimes take these on together, such as e.g. collecting all the water from drainage or helping each other reach a tough height [50]. Within the TOPO categorization, 'work play' falls under play with rules and is typically organic, but could potentially be conventional depending on how closely the installations guide its rules. Due to its prevalence in play with digital installations we made special note of instances of work play.

3 METHOD

Children's self-directed play was observed in four different settings with access to a range of play materials. Below, the settings are

described to illustrate the variety of materials and environmental features that influenced the children's play, and then the digital installations included in the study are described. We finally detail how data was collected and analysed.

3.1 Settings

The selected settings were chosen to cover nature-rich environments with and without digital installations, as well as with and without dedicated play equipment such as swings, climbing frames, and benches. The reason for including also traditional playground installations was to allow us to understand to what extent the play behaviours emerging with digital installations would also emerge with other artificial installations. All four settings were around 3500 square meters and offered access to nature features and loose materials. Finally, all four settings were authentic outdoor environments, and the installations were in place permanently or semi-permanently. The settings were roped off for the duration of the study.

- "**Mixed**" was located in a park that includes two digital installations: the "hut" located within and the "eggs" located on the border of a forest area. The setting also included a traditional playground with swings and various climbing gear, and parts of the surrounding park. The latter is dominated by lawn but adjacent to the playground there are some boulders surrounded by grass of meadow character.
- "**Digital forest**" was located in a forest and included three digital installations (the "sound poles", the "light poles" and the "tubes" and two non-digital installations. The forest is dominated by conifer trees, with much visible bedrock and stones and some ferns and shrubs in between, and large trails of trampled land across the area. The non-digital installations were 1) a large hand sculpted out of wood, that was climbable, and 2) a large metal ring hung high between three trees, about three meters above ground, out of reach for the children. Else, the area was similar to the Forest setting described below and had both trees and ravines. The ground was however more trampled and had less moss and berries.
- **"Traditional"** was located in a park with traditional playground installations and no digital installations. This setting included a climbing frame with a slide, four swings, a sandbox with a small wooden house, all adjacent to a large open grass area also including perennial and shrub plantings, seating, a number of trees and a paved walkway across the area.
- **"Forest"** was a forest area without digital installations containing small groves, one particularly high spruce, a small ravine, a high cliff overlooking the area, some slopes and trampled nature trails across the ground with an undergrowth of blueberry and lingonberry.

A previous publication [66] was based on quantifiable data (including step counts, behaviour tracking and questionnaires) from three of the sessions ("Forest", "Digital Forest", and "Traditional") to elicit macro-scale differences in play engagement between them. The most notable difference between these three sessions was that the children in the forest setting engaged in play that was more versatile, with higher incidence of imaginative play and physical activity than in the two other settings. The article also reported that out of these three sessions, the children reported lowest scores for satisfaction in the Digital Forest setting. The analysis reported in this paper is based on the data from these three sessions plus the Mixed setting obtained using the same methods as described below, but uses qualitative data (video recordings, observation notes, and interviews with the children) from all four sessions to go more in depth on the children's play engagement, thus contributing with a qualitative understanding of how the macro-scale differences may have emerged.

3.2 Play session setup

One observation session was carried out in each of the four settings. The observation sessions in the "Traditional", "Digital Forest" and "Forest" settings were conducted during October 2020. Children from the same nearby school attended all three sessions. A fourth session (in the "Mixed" setting) took place in March 2021 in another city, with children participating from a nearby school in that city[3].

In each observation session, groups of 14–17 children aged 7–8 took part. Written consent was obtained from parents. To ensure the children's own consent, children were verbally informed about the purpose and setup of the study before each session, and informed that they could choose to not participate or drop out at any time.

The sessions were run in the same way in all four settings. Each area was roped off in order to restrict observations to the children who had consented to participate in the study and their teachers. Each child was equipped with a numbered vest (for identification on video) and a step counter. The children were informed that they could play whatever they wanted within the roped-off area. After 45 minutes all activity was aborted by a teacher blowing a whistle. Researchers would then gather groups of children to perform 'walk and talk' interviews, during which the children told the researcher about what they had been playing and what materials they had been using. Finally, each child filled out a written questionnaire containing scaled questions on their activity and experience of the session, with the support of a researcher and/or teacher when required. (The step counter and questionnaire data are not discussed in this article.)

The study was submitted for ethical approval to the Swedish Ethical Review Authority, that concluded that no ethical approval was needed.

3.3 Data Collection

This paper builds on data from play tracking, video recordings, and interviews with the children.

Play tracking. The play tracking consisted of structured observations, and were carried out by the same researchers in all four settings. Each play setting was divided into three zones, with one observer in each zone making notes of the activities. The researcher stayed in one zone for 15 minutes, and then rotated, visiting all zones at least once during the full observation session. Each situated play episode was documented in a field note protocol (see Figure 1).

[3]The observant reader might notice that all four sessions were run during the pandemic. The study was possible since schools and after-school activities were not closed in Sweden during the pandemic. However, in one of the sessions (the "Forest" session), parts of the research team could not participate due to recommendations concerning travel to and from the city where they lived.

The protocol included a map of the area, and had dedicated slots for documenting the play types according to the TOPO-typology [48], the time of observation, the materials children used, and an assessment of children´s expressions of mood (the latter not used in this article). A custom-made selection of the materials used by children was pre-scripted and included both nature materials such as sticks and water, fixed nature features or artificial installations, and digital audio or visual feedback. The list had space for noting down materials not on the list. Finally, the protocol had space for making open field notes, for example documenting the children's dialogue.

Validity and reliability of the tracking were improved by observers having trained on classifying children's play. A post-session analysis of data showed that the same situated play episodes had been identified with observer agreement on the major TOPO classifications for these, although there were some discrepancies in the sub-category classifications.

Video documentation. Nine GoPro cameras were used to document each play session including the post-play walk and talk interviews. Before the play sessions, the cameras were placed in strategic locations. Each camera was either dedicated to providing a close-up capture of installations or environmental features that were likely to inspire play activity, or presenting an overview of a larger area. Apart from capturing movement and activity, the close-up cameras were also able to capture some of the dialogue between the children. The location and angle of video capture for each camera were plotted on a map. In each session, four to five cameras were focussed on specific installations or landscape features, and the rest were used for providing overviews covering the roped-off area as thoroughly as possible. The photos used in the article have been extracted from the video recordings. Children visible on video have been anonymized through being redrawn as black body shapes.

Post-Play interviews with the children. After each play session, the researchers gathered the children in groups of one to four, based on the location they were in and the group they had been playing with at the end of the session. This way, the children were interviewed in self-selected groups that had been playing together at that time. The interviews were carried out in a walk-and-talk manner, with the children showing us where and how they had been playing. The interviews were video recorded.

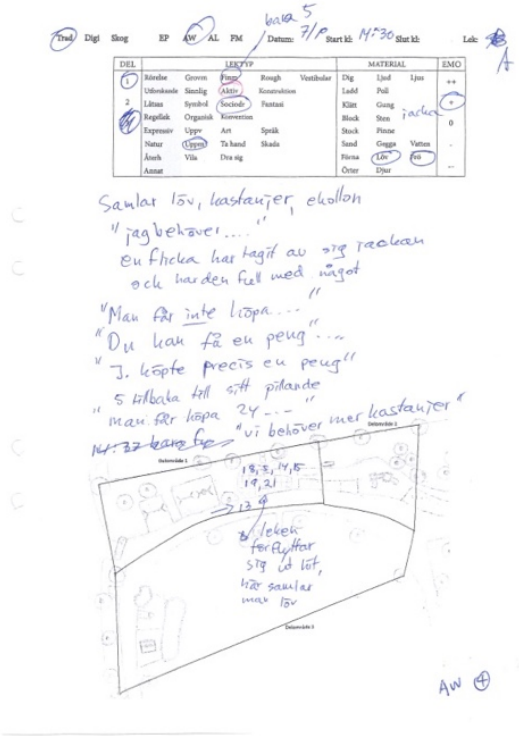


Figure 1: An example play tracking form, with field notes. The example follows part of the 'Shop' episode which took place in the Traditional setting. The note begins thirty minutes into the session, and describes a part of the play episode when a large group of children already had become interested in the shop. The protocol uses the TOPO codes "Active" and "Sociodramatic" to describe the activity. During the analysis phase this episode was recoded as Constructive and Sociodramatic.

3.4 Analysis: Identifying and Describing Situated Play Episodes

This article uses "situated play episodes" [50] as its object of analysis. Mårtensson (IBID) describes these as a way of organising children's play activities into identifiable units characterized by one or several of the following elements: 1) a core group of children involved, 2) a place or central object which children attend to, or 3) a narrative lingering in the episode, or set of rules negotiated. Situated play episodes evolve through interactions with peers and place, making them both visually and audibly observable (IBID).

The identification and documentation of situated play episodes was done in three steps. Firstly, the observation protocols from play tracking by multiple observers were combined, when they documented different phases of the same play episode. A few, short-lived episodes were only documented by a single observer, but most were documented by several, as the observers rotated between the different zones. Next, field notes were matched against the video recordings to create a more precise description of their duration and participants. This required reviewing all video recordings to identify video recordings that captured the observed episodes, but also to see if some episodes could be identified that had not been observed by the observers. During this review, we also made complementary notes of environmental features and materials used in each identified situated play episode. For easy reference, each situated play episode was named, denoting the activity and/or feature in focus, and sometimes its social set-up. Finally, play episodes were transcribed based on a combination of field notes and video recordings, including their timing, children's utterances, observable interactions and use of material. The post-play interviews were transcribed to supplement the observations with children's account of their play experience. Based on the combined data for each episode, the TOPO classifications [48] done during observations were also revisited and refined. The process involved at least two

Figure 2: The three installations in the Digital Forest setting. Top left: The Tubes. Note the led panel at the leftmost hut construction in the back of the picture. The pole placed between them is non-functional (it distributes electricity). Top right: The Running Poles (photographed from the forest side). Bottom: The music poles.

researchers reviewing the video material for each identified play episode, and contributing to its transcription.

An overview of all documented episodes is available in Appendix 1. Episodes are classified according to their main TOPO classifications with an additional note of instances of Work play. Each episode is classified into one or two categories. When possible, we also discriminate between sub-categories for each play type.

The table also includes the materials that the children engaged with during the episode. This list has been compiled from observer notes and video analysis. Digital installations are listed as materials as soon as the children engaged with them in any way at all, even if brief. In all except one play episode they also engaged with their interactive functionalities. The one exception is the *Old Witch* episode, which is made special note of in the table. The table also includes short descriptions of the play behaviour and the number of children involved.

It should be noted that while the data collection and analysis process allowed us to develop a rich and in-depth understanding of the children's play episodes, the analysis does not cover all episodes that emerged. The video recordings captured fragments of episodes that are too incomplete to be transcribed, and it is possible that some play episodes were missed by both observers and cameras.

3.5 Digital installations

The five digital installations included in this study were all designed to be placed in nature-rich settings. All are also open-ended designs, leaving space for playful exploration and social negotiation, and some had been designed with the specific intention to interact well with nature play. Furthermore, their placement in the surrounding landscape had been done with attention to how they can entice children to play in nature-rich settings. Hence, they are particularly well suited for our study. Their designs are however quite different, both in what play activities they support and the motivations underlying their designs. In this section, we present the five installations included in the study and the rationale behind their designs and placement. The digital installations were present in two of the settings: the digital forest contained three installations (The tubes, The Running Poles and the Sound Poles), and the "Mixed" location two (The Eggs and the Hut).

3.5.1 The Tubes. The Tubes are a semi-permanent installation in a forest area (see Figure 2) combining two tubes equipped with sensors, and both sound and LED panel feedback. In line with the bricolage approach towards integrating technology with nature play suggested in [80], the installation is designed to integrate play with nature materials in green settings with engagement with

the Tubes [65]. The two tubes are equipped with sensors that are triggered by moisture, sound, and movement which allows them to react to qualities that different types of nature materials can have. One sensor responds to movement for objects such as pine cones, stones, sticks, leaves, or moss. A sound sensor reacts to vibrations when heavier objects such as stones rattle through the tubes. Finally, a moisture sensor responds to wet items such as water or damp moss. Adopting an open-ended design approach, the Tube installation does not implement a clear goal but lets the children incorporate the feedback in their play narratives. The sounds used for feedback reflect the properties of the materials: wetness is signaled through the sound of running water, vibrations with the sound of a rolling stone, and the movement sensor is connected to a tingling sound. The visual feedback comes in the form of three light pillars in blue, green, and red that represent each of the sensors.

A wooden frame 'play hut' complements the installation with an additional LED feedback panel that provides combined feedback from the tubes. This setup offers opportunities for fostering social play, with children taking different roles in interacting with different parts of the installation. Previous studies with similar installations have reported that the setup can foster work play [4, 8].

The tubes were carefully placed at the site in dialogue with the local municipality authority, to be visible from a regular park nearby, this in order to invite play in a forest area that previously had been very little in use. The place was also carefully considered to provide a 'den' feeling, by how the tubes were partly enclosed by two larger rocks.

3.5.2 The Running Poles. These poles were placed close to the border of a regular park (see Figure 2). This installation consists of four poles in a circle containing a multi-coloured light source and a speaker. Each pole has a button on its top surface. Pressing a button on one pole triggers another, random, pole's light and sound. Each pole has a different animal sound. Both light and sound then fade gradually, unless somebody presses the button at the top of the pole which in turn triggers another pole. The design of this installation built on positive experiences in previous studies with similar installations [8], which indicate that they can foster a variety of playful games. The main design consideration for this installation was thus to be open-ended, so that it could be used for a number of games and playful activities [65]. In dialogue with the municipality, this installation was placed at the very border of the nature-rich area, so that it could be accessible by wheelchair as the ground material is hard gravel connecting to grass.

3.5.3 The Music Poles. This installation is based on the same type of interactive poles as the Running Pole installation, but the nature around this installation is wilder with high grass and ferns and uneven terrain (see Figure 2). These are landscape properties that commonly inspire nature play, and the purpose of using this location was to connect the installation closely to the nature surrounding it. The uneven ground and the more fragile greenery made this spot unsuitable for the running poles, why this installation implemented a different function. Five poles are placed in a circle, and programmed to change colour and produce different sounds each time they are pressed. Each pole has a unique playlist, containing beats, vocal sounds, ambience sounds, or musical instruments, contributing to a complex sound landscape and supporting collective music generation [65]. The placement of this installation was also done in dialogue with the municipality, The location was chosen so that the poles would be less visible from the regular park area but instead clearly visible from the other two digital installations, so that its placement would encourage moving through the forest area.

3.5.4 The Eggs. The Eggs are permanently installed on the border between a forest and a traditional playground area in the Mixed setting (see Figure 3). The Eggs were designed in close collaboration with the municipality, with a strong focus on core values stated by the municipality including democracy, inclusivity, accessibility, and pedagogical purposes [6]. Their placement is intended to function as a link between the forest and the traditional playground, where the playground works as a play invitation to both children and adults, and the eggs may entice them to move also into the forest area.

The eggs are two identical one-metre-high eggs inspired by wild bird eggs, dug into the ground, and digitally connected to each other so that actions at one of them can affect the other. Each egg has 16 touch-sensitive areas that can light up, and the eggs can produce a variety of sounds. Just as the running poles, one of the eggs is placed to be wheelchair accessible through a dirt road. The other, placed about 5-10 meters into the forest does not have any dedicated walkways, a placement that is intended to draw the children into the forest just as the placement of the Tubes. Furthermore, the eggs are placed so that the view between them is semi-obstructed by a tree, to further integrate them into the surrounding landscape and turn the tree into part of the playing, when interacting between the eggs.

The eggs are reprogrammable through a graphical online programming interface [5]. At the time of our observation session, the eggs offered one idle behaviour and three different play behaviours. When idle, the eggs pulsated in different colours. When they were touched, one of the play behaviours would start, depending on the current colour of the egg. The scenarios were 1) a running-hunting scenario, where one dot would light up, and when touched it would move to another position on the egg. 2) a scenario where dots would light up randomly, and then slowly fade away. By touching the active dots, they would light up fully again, and this way they could be 'kept alive'. 3) a colouring scenario, where dots would change colour each time they were touched, making it possible to paint the egg into any colour the participant wished. This scenario was mirrored between the two eggs, making it possible to affect the other egg across distance.

3.5.5 The Hut. The Hut was designed during the same process as the eggs, in close collaborations with the municipality, and with a strong focus on the same core values. It is a permanent installation, placed in the forest area in the Mixed setting and close to the eggs described above (see Figure 3). It is accessible via a small dirt road from the traditional playground. It is intended to afford also calmer forms of play, listening, imagining, and relaxation and has a strong focus on storytelling in line with what is suggested in [25]. Just as the Eggs, the Hut is reprogrammable and several play behaviours can be offered [5]. At the time of testing, three behaviours were

Figure 3: The two installations in the Mixed setting. Left: One of the two Eggs. Right: The Hut.

active: 1) a scenario containing short stories about the animals in the forest, based on the actual fauna in the park. The animals in the stories are also present in the area in the form of small statues. 2) a music scenario with upbeat music, making the Hut resemble a disco, and 3) a completely silent scenario with steady lights, for calm play or play activities where the other behaviours would not be appropriate. A long-term study of the hut has shown that the story-telling incorporated in the installation can spur story-informed play in the vicinity of the hut [40].

The hut has one round window and is designed to resemble a bird house. Inside are four interactive tree stump stools, one in each corner, and four spotlights in the roof each aimed at one of the stools. In the ceiling, there are additional multi-coloured mood lights and loudspeakers. The stools are equipped with sensors that can sense if somebody is sitting on them. The hut is made out of unpainted wood, letting it take on more and more of a natural colour over time, and it is placed so that the door faces the forest, making nature the main view when sitting down inside.

4 Results

4.1 A Play Type Analysis of the Observed Episodes

Appendix 1 presents a full overview of the situated play episodes together with their play types and the materials that were observed being in use. Table 2 maps the materials used in play episodes against the dominant play types of the same episodes. To correspond to our first research question, the table distinguishes between digital materials, nature materials including fixed nature elements (e.g. boulders), and other artificial materials including both fixed installations and portable artefacts (e.g. balls and buckets). Since several play episodes had multiple play types and involved several types of materials, the play episodes sometimes occur in multiple places.

The dominant play types of the observed episodes were restricted to sensory and gross motor play, active exploration, imaginative play, organic rule-based play and a few cases of constructive play (see Table 2). As can be seen already in the table, there is a distinct difference in how different types of materials were used in the different types of play. In particular, organic rule-based play being almost solely associated with digital installations and imaginative play with nature materials. Below, we will discuss each of the play types in more detail. Furthermore, we can see how active exploration almost exclusively emerged with digital materials.

Two play episodes are described more in detail as examples of how organic rule-based play emerged with digital installations, and imaginative play with nature materials. These are included as Vignettes. Both are also examples of sustained and quite elaborate play activities, involving groups of children and fluctuating in different ways. Both are also well documented on camera and in observer notes. Compiled transcriptions for these two episodes can be found in Appendix 2, including observer notes, video transcripts, and excerpts from the interviews.

4.2 Organic Rule-based Play is Common with Digital Installations

4.2.1 Vignette: The Light Chase Episode. The Light Chase episode (4) emerged in the Digital Forest setting and lasted about 18 minutes total, with some short breaks in between and with children now and then joining and leaving the episode. It is recognizable as an episode through the way in which a consistent set of rules is developed, through some of the materials in use (in particular, the running poles) and through a core set of children that are involved throughout. A compiled transcript of the session can be found in Appendix 2.

Table 2: Overview of the dominant play types and materials in the play episodes. Note that some play episodes are listed multiple times, if they shifted dominant play type or used multiple types of materials.

Dominant play type	MATERIALS		
	Digital installations / digital artefacts	Loose nature materials and/or fixed nature features	Non-digital artefacts and/ or installations
Gross Motor	Sound Poles	Sticks Duo	Swing-Duo
		Zombies Duo	Climbing-solo
		Hand Duo	Swing
		Tumble	Climb
		Don't Touch Ground	Plank
		Trees Duo	
Sensory Exploration	Sound Poles	Spruce Tree	Bucket
	Eggs	Collect-Solo	
		The Ravine	
		Pick Berries Duo	
		Collect-Solo2	
		Sticks	
		Bucket	
Active Exploration	Light Chase	Tubes	Ring
	Tubes		
	Eggs		
	Playhouse		
Organic Rule-based	Light Chase	Don't touch ground	Ball
	Run-solo (with step counter)		
	Playhouse		
Imaginative	Old Lady	Spruce Tree	Plank
		Sticks Duo	Old Lady
		Zombies Duo	
		The Ravine	
		Minecraft	
		Tumble	
		Shop	
		Evolution	
		Old Lady	
Constructive		Shop	Ball

The episode starts with an active exploration phase during which the children investigate the function of the poles. The way in which the light can jump from pole to pole is discovered fairly quickly. After about two minutes, an informal leader takes charge and suggested a running game. (The informal leader seems to be one of the most interested in this installation, later turning back alone.) Negotiation emerges about who gets to run and who gets to guard the poles.

The game that evolves is however different from the suggested: two children stand guard at one pole each, and the third runs after the light that now jumps between the remaining two poles.

After approximately seven minutes, three more children arrive. The children at the poles, who have already developed an organic rule-based game, instruct the newcomers in what to do. However, the game breaks down as there are now more children than poles so there are no more poles to run between. Due to their intense button pressing, they instead discover a new function with the posts: they start blinking intensely when all buttons are pressed at once. The play activity now changes into trying to recreate this effect. A noteworthy utterance at this point of time is the "harder, harder, we have to fill it up", indicating work play [8]. Many of the children use sticks to hold the buttons in. One child starts dancing in the middle of the ring of poles while hitting a multi-stemmed birch with their stick, possibly as if it was their pole.

After this, the play episode ebbs out. One possible explanation for this is that there are now too many children for the number of poles. An alternative and complementary explanation could be that standing still and keeping a button pressed is not a particularly fun activity.

In the post-play interviews, the children described how the episode changed nature when the children discovered a new function:

> *Child 1: We chased the lamp. When you click on it, it goes somewhere else. And in the end, we held them in... (points excitedly in front of him) ... because then ... then it kind of goes straight in there, because if you*

Figure 4: Children Playing at the Running Poles. The two children in the background are using sticks to press the buttons. The child in the middle is doing a dance-like acrobatic movement while hitting the tree with a stick.

Figure 5: The Tubes Episode. At the time of the photo, a large group of children are busy carrying water in small buckets from the big bucket visible in the middle. They are also poking a stick into the frontmost tube. The led panels are lit, visible on the front tube and the hut in the back of the photo.

> *kind of hold it with your finger, it's probably... or with sticks... then it sinks in...*
>
> *Child 2: Also, it doesn't hurt that much*
>
> *Child 1: Well, when we hold it in, it flashes*[4]

The *Light Chase* episode in the Vignette is an example of how digital installations inspired organic rule-based play. A common element of such episodes is that they start with a phase of active exploration (see Table 2), in which the children explore the functionality of the installation. The episodes also tend to have an informal leader how instructs the others and coordinates their play activity. The leader's suggestions are however not always accepted, and can be followed by transgressions and negotiation of rules and roles [7]. The role as 'leader' can also be challenged, as when in the *Light Chase* episode, the child with a stick who is dancing in the middle also attempts to instruct the others. In literature, this type of hierarchical social structure has been considered more common with the presence of fixed playground installations than in nature settings [50].

[4]All quotes have been translated from Swedish.

Figure 6: Four children pretending to live in Minecraft. This image captures their play on a small hill on which they made their home. At the captured moment they seem to be cooking and eating.

Another instance of organic rule-based play emerged with the Tubes in the Digital Forest, which inspired an intense play episode (see Figure 5) lasting about eleven minutes and involving most of the children present. The *Playhouse* episode in the Mixed session was of shorter duration, but otherwise similar to these two sessions. We observed only one organic rule-based activity that did not involve digital installations or digital materials: the *Ball* episode in the Traditional setting. This episode developed around a climbing gear installation and is further discussed below.

4.3 Nature Nurturing Imaginative Play

4.3.1 Vignette: The Minecraft Episode. The Minecraft play episode emerged in the Forest setting (see figure 6). It was identified as a consistent episode through its uniform narrative and the group of children involved. The episode lasted for almost the entire observation session, and involved four children with occasional visits from other children. It also moved over a fairly large area with a designated 'home'. Minecraft is a computer game that is popular among children this age, built on a sandbox paradigm. A compiled transcript for this episode can be found in Appendix 2.

The suggestion to play Minecraft appeared as soon as the children had entered the setting. One of the children repeatedly proposes to go witch hunting ("Come NN we must kill the witch"), but the main activity centers on developing their home and the finding materials they need. Early on, the group select a large spruce with an open space below as their home. When another group appropriate the same tree, the Minecraft team move their home to a small height covered with moss. They gather lingonberries to be their food. They make a stove out of moss and scavenge sticks to be used as weapons. Some important elements remain entirely imaginary, including a safe, a helicopter, and an indestructible door.

Once the home is decently established, they start playing that darkness is falling. (In the Minecraft computer game, this means that dangerous creatures are afoot and that you have to stay indoors.) The following dialogue was captured on video:

> *Hello, it is starting to become night!*
>
> *Hurry, it is beginning to become night!*
>
> *Here is our house, here!"*
>
> *The zombies are coming!*
>
> *They can come in!*
>
> *We have to make a fire!*
>
> *A witch!*
>
> *Shut! Shut!*

This play episode was discussed quite extensively during the post-play interviews. The children told us that they would sometimes play Minecraft also in the school yard. When asked about what materials they needed to play this game, they said that the game can use a variety of materials:

> *You can have stones... sticks, a mountain to be on and lots of moss, and imagination... and blueberries*
>
> *Sticks*
>
> *And stones*
>
> *And pine sprigs*
>
> *Instead of stones*
>
> *And instead of stones, we had moss because it's much easier to find*

Children playing Minecraft in the physical world has been documented previously [58]. The *Minecraft* episode is a good illustration of imaginative play, even if it also has some rule-like elements due to its narrative as a computer game. Imaginative play was almost solely observed in connection to nature features in the landscape. It often made use of loose nature materials, emerging in combination with sensory exploration (and in our study, often in relation to picking and eating berries). In the Minecraft episode, a host of nature materials are used. As is typical of symbolic play, some materials are also resignified, that is, they are used to represent something that becomes meaningful in the fantastic context. An example is how the stove is made of moss and how sticks are used to represent weapons. In this particular episode, some play elements also remain entirely imaginary, while still placed physically in selected locations. For example, one of the children showed us

Figure 7: The Old Lady. The girl in the house is mimicking an old lady chasing away the others using her walking cane. She has made the hut her home, and the other two children are sneaking up on her.

their imagined safe by gesturing to a particular place during the post-play interview.

Imaginative play in nature very often roamed large areas, sometimes settling temporarily or permanently by appropriating a place through constructive play. The children playing Minecraft had a home base and moved it once, but also roamed a fairly large area. To mark the location of their house, they created a fire stove (constructive play).

In our study, extended sessions of imaginative play were typically accompanied by intense dialogue. Some play initiatives were not picked up by the group, such as one child repeatedly wanting to go "witch hunting". When a play initiative was picked up it was typically reiterated verbally by several participants ('It's getting dark! The zombies are coming!"). It has been noted in literature that verbal negotiation is needed less in green settings, as affordances of nature also help to coordinate the activity [50].

Several other imaginative play episodes were observed in the Forest setting, such as the *Spruce Tree* episode in which a group of children were playing house under a tree. Other examples of imaginative play episodes include *The Old Lady* (Mixed setting) play episode, which relied heavily on a pretence performance. One girl pretended to be an old grumpy lady who chased away everyone else when they came too close (see Figure 7). The children involved in this activity used sticks to represent both weapons and canes, and roamed the whole play area rounding the digital Egg installations several times. The *Evolution* play episode in the Mixed setting was also heavy reliant on the children pretending. In this episode, a group of children roamed the area picking up "powerups" to help imaginary creatures evolve. Just as in the safe in the Minecraft episode, their "creatures" were entirely imaginary, but the children chose locations for their powerups based on landscape features in the environment, in particular revisiting a meadow area several times. The nature in the meadow area, including loose leaves, visiting birds, water puddles and boulders, might have contributed to the overall vitality and longevity of this episode. In all of these episodes, it was predominantly nature materials that were resignified to represent something else.

4.4 Sensory Exploration is Common when Interacting with Nature

Most sensory exploration and gross motor play episodes made use of nature materials. The sensory exploration of such materials was often at the core of the more loosely organized play episodes, in which the children roamed across the play setting trying out its various affordances. Especially in the Forest, we observed how children would touch, bend and stroke twigs or small trees that they passed along the way. Sensory play engagement ranged from the casual 'touch in passing', to intense engagement such as when the children went searching for, picked and ate berries in several of the episodes (for example *Minecraft* and *Pick Berries Duo*).

As discussed in the background vestibular and gross motor play also involve sensory exploration, in these cases directed towards the own proprioceptive senses. Both in the Forest and the Digital Forest settings we observed episodes of gross motor play of the 'the floor is lava' kind, (*Zombies Duo* and *Don't Touch Ground*), in which the children were balancing and climbing while roaming

Figure 8: Three children dancing around one of the eggs..

the entire area. This roaming behaviour was particular for play in nature-rich area: in the Traditional and Mixed settings, similar gross motor play was more stationary with focus on fixed playground installations. In the Digital Forest area, a hand sculpture was a popular location for climbing, offering both gross motor activity and sensory exploration of the carved surface. We also observed one instance of 'Rough and Tumble' play (the *Tumble* episode in the Forest setting).

Sensory exploration was often ongoing in parallel with imaginative play, and/or with the children being engaged in intense dialogue. Examples include the two children swinging and talking in the Traditional setting (Swing-Duo) and the children moving around in a ravine in the Forest area (The Ravine). In relation to the digital installations, sensory exploration was briefly documented with the Eggs (e.g. Figure 8) and the Sound Poles. In particular, the children would climb on the eggs, run around them, and randomly tap their interactive spots.

4.4.1 Constructive play Recruiting Malleable Materials. A particularly elaborate form of sensory play emerges when materials are actively collected and re-shaped. Several episodes became dedicated to the collection of nature materials such as leaves, pinecones and chestnuts. In the traditional setting, an abundance of loose leaves and chestnuts became the focus for children´s play, eventually merging into one and the same episode (the *Shop* episode) in which a group of children created a chestnut shop and museum, and invited the others to visit. This episode lasted for almost the entire observation session and grew to include almost all of the children present. The participating children took clear pleasure in the aesthetic qualities of the leaves and the chestnuts, and in particular the museum was artistically executed with chestnuts arranged on the wall by a flowerbed with care and attention to detail.

Constructive play was mostly observed in conjunction with imaginative play (such as when the children collected moss and built a stove out of it during the *Minecraft* episode), but in one case with organic rule-based play. This happened in the *Ball* episode, see Figure 9, in which a group of children developed a ball-throwing game. This game was about throwing a ball from a climbing tower to the ground. One of the children created a large target in the sand below the climbing tower, effectively re-purposes the entire climbing tower from climbing into supporting their ball-throwing game. In our study, we did not see constructive play emerge in conjunction with digital materials.

Constructive play requires access to an abundance of loose materials, which we will discuss further in the next section.

5 Digital installations and nature materials inspire different forms of play engagement

In the results section, we uncovered some salient differences between the play episodes emerging around digital installations, and those emerging in relation to nature and natural materials. In this section, we will dig deeper into orthe possible reasons for these differences.

We must first note that most of the digital installations showed capacity to inspire open-ended play in the sense it has been described in play technology literature [9, 10, 75, 76]. They were installations attractive to the children inviting them to explore their different functions and also evolving into a phase of immersion, as described by De Valk et al [75], as intended by design. What stood out in this study, comparing play episodes across a more diverse set of settings, was how *different* this form of engagement was from the children's engagement with nature materials, and the implications of this for the overall play flow. We have shown in the results section how children´s interaction with digital material tend to

Figure 9: Children collaborating in designing a ball-throwing game. In the photo, the informal leader is busy constructing a target.

develop into informal rule-based play, while their interaction with nature material evolves into more elaborate play sessions including imaginative play, sensory exploration, and constructive play. In this section, we discuss what may underlie these differences.

5.1 Active Exploration is not Typical of Nature Play

There was a systematic difference between how the children initiated their play with digital installations, and how they began to play with nature materials. With the interactive materials, the children initially engaged in active exploration [48] (see Table 2) scrutinizing their function. An example of this is how the children first investigate the poles in the *Light Chase* episode, and similar behaviour was observed in all instances of organic rule-based play with digital installations. While active exploration could presumably emerge also in nature play, we did not observe it in any play episodes centred on nature materials. The likely explanation for the difference is that the designed affordances of the digital installations were at the same time more limited and more difficult to understand for the children, than those offered by nature materials. Engaging with the digital material thus required active exploration to figure out their functionality, and it was only after deciphering (at least some of) the functionality that more playful interactions begun to emerge. There was only one other episode documented in the material in which a non-interactive material was approached in a similar way: the *Ring* episode in the digital forest setting, when the children mistakenly believed that a non-functional installation might be interactive and kept exploring its functionality.

The difference between active exploration and sensory exploration helped us understand how children´s response to nature material differ from their response to digital materials. While active exploration of a material can be a vital dimension of education and learning [37], our observations indicate that it was not very playful for the children. If the exploration did not bring about an understanding of the functionality fairly quickly, the interactive installations were abandoned. (An example is the *Playhouse* episode.) This speaks against some earlier play literature which suggests that active exploration can provide playful learning opportunities [37, 76]. Play characterized by sensory exploration, drawing on the aesthetic dimension of nature, sometimes lasted for extended periods paving the way for imaginative play.

When children engaged in exploring the functions of interactive installations, this strongly influenced how they subsequently played with them. The uncovered affordances inspired social rules that the children would suggest, negotiate and agree on. Furthermore, despite the fact that all digital installations were designed to be open-ended, several organic rule-based episodes included a goal, implicitly indicated by the installations. The tubes installation is a clear example of this, in how the children quickly adopted the goal of 'filling up' the feedback bars, resulting an intense work play episode. The designed affordances of digital installations were also sometimes suggestive of roles for the participants to take on. The children could for example divide the interactive functions between themselves, such as at when the children in the *Light Chase* episode adopted one light pole each.

Previous research has pointed out how easily interactive tools give rise to competitions, especially when accumulated feedback is used [35]. While we did not observe player to player competitions,

we did observe work play [8], which can be seen as the whole group competing against a challenge offered by the technology or the setting.

The designed affordances, implicit goals and suggested role division together explain why play episodes by digital installations tend to become settings for organic rule-based play, and have a hard time to gain the more fluent and versatile dimensions of children´s play which evolved in settings with nature and nature materials.

5.2 Nature Excels in Supporting Sensory Exploration

While nature material inspired sensory engagement – so called sensory exploration – this was only rarely observed with artificial materials or digital installations. The latter is surprising, as all of the digital installations provided light and sound feedback, that in the cases of the Eggs and the Sound poles were quite elaborate.

Nature settings, with their abundance of loose materials, excel in offering sensory exploration. Nature offers a level of complexity and high-resolution aesthetics speaking to many senses, so that deeper inspection almost always uncovers new findings. The aesthetic qualities of nature materials can inspire long-lasting and aesthetic engagement, as in the *Shop* episode where the activity revolves around the different leaves and chestnuts being evaluated, sorted and displayed.

In our study, among the digital installations the Egg installation in the Mixed setting stood out, in terms of being aesthetically pleasing through their organic shapes and texture, with coordinated sounds and coloured lights. The Eggs were recruited into play in several play episodes. While they sometimes were actively explored, they were also incorporated into episodes in open-ended and fluent ways, such as in *The Old Lady* discussed above. This resembled how children often would roam the environment gathering a variety of sensory experiences in nature play.

A particularly strong play invitation was observed when children got access to an abundance of loose materials as in the *Shop* episode, which took place a sunny day during those weeks in the autumn when there is an abundance of chestnuts and leaves. Loose materials are recognized as vital for children´s self-directed play in general [36, 55] and the accessibility to such in nature is an important dimension of play in nature. Some materials such as sand and sticks lend themselves to constructive play, water can be gathered and poured out (as in the Tubes episode), ice and stones can be cracked, leaves and pinecones burned, berries ingested, etcetera.

While it is difficult to see how digital installations can become abundant in themselves, the Tube installation was designed to capitalise on the presence of abundant loose materials, encouraging children to collect sticks, pebbles and water etcetera and place them in the tube to investigate its different effects. However, as work play emerged, the children's focus shifted from the aesthetics of the materials themselves towards the collective goal of 'filling up' the feedback bars. The aesthetic qualities of loose materials that in other play episodes inspired sensory exploration and imaginative play, here became overshadowed by their role of being "fudder for the machine" – and eventually the water ran out. While it has been suggested that digital technology could support creating a stronger affinity to nature, this type of effect could work to the contrary [18].

An abundance of digital resources is entirely possible, as illustrated by the original Minecraft game [12]. Studies of online play also indicate that it can offer aesthetic experiences similar to nature experiences [74]. Hence, the digital material offers opportunities for abundance, that potentially can be achieved using movable play-tools such as the glowsteps [22], by using mobile technology to inspect nature [39], or by making fixed installations re-programmable by their end users [5].

5.3 Digital Materials Tend to be Unfantastic

Looking at the sustained play episodes, we see a clear difference between the ones inspired by digital materials and those supported by nature materials. While the active exploration of digital materials primarily inspired organic rule-based play, nature materials were associated with sensory exploration paving the way for imaginative play. An explanation for this difference could be that having access to an abundance of nature materials was important in resignification, as materials could be collected and shaped to resemble what they represented. Previous research also points towards how children take impression and fetch cues to their play activity from the surroundings in fuelling their fantasy [44]. In this respect, nature provides a rich and varied resource.

Furthermore, when recruited into imaginative play, nature materials were mostly resignified. We did not observe any play episode where the digital installations were used to represent something else. The most likely reason for this is how the initial active exploration of the digital installations tended to inspire rule-based play rather than imaginative play. While related work has reported observations of meaningful sounds triggering children's fantasy [36], there is a risk that symbolic feedback can become too precise (e.g., an installation producing the sound of a cow would restrict it to represent a cow). This would again hamper resignification and limit the possible roles of the installation in play.

6 Design Challenges and Opportunities

Based on the analysis of children's play engagement, we now turn to our second research question to pose some design challenges and opportunities for future design of digital technology for play in nature.

6.1 Design Challenges for Digital Outdoor Play Installations

The observation that digital installations fosters play in a different way than nature materials is not problematic per se. Digital installations can still enrich a space to offer a wider palette of play activities than impoverished everyday settings could offer otherwise [3, 8]. Digital installations can also foster exertion, e.g. through inspiring work play, or have educational purposes. Previous studies show how digital materials can function as invitations [8, 66] to investigate and engage with spaces that otherwise might be perceived as uninteresting or scary. Hence, digital installations can function as invitations to explore nature, in particular for children having little

experience of playing in intimate contact with nature. This was considered in the placement of the installations included in this study, and in this sense the installations were also largely successful.

However, we believe that previous digital design work for play in nature has over-emphasised the value of both competitive play and learning outcomes, over the importance of children's self-directed play. As brought up in the background, the health and pro-social benefits of play in nature have been observed with children engaging on their own terms and have been argued to outweigh the benefits of more organized activities in nature [79]. There is no guarantee that these benefits persist when play activities become disciplined into learning activities or games.

There is also a risk that the digital materials will compete with nature for the children's attention. Nature risks becoming instrumentalised as in the *Tubes* episode, and at a larger scale, digital installations may overshadow the presence of nature. This may have happened in the Digital Forest setting, as children did not engage as much with the nature resources available in this session as they did in the Forest session, despite having ample access to nature materials in both.

6.2 Design Opportunities for Outdoor Digital Installations

In order to ensure that play in nature maintains its documented developmental and health benefits, designers need to place increased focus on the kind of roaming, fluent and fluctuating playful activity which is its signum. This requires increased attention on how interactive installations can interact with their surroundings, present a richness in the aesthetics in form and feedback, and take into account the surrounding landscape. In this, the design of interactive installations can draw on available knowledge on how nature is supportive to human functioning at large and children´s play in particular. The following guidelines provide a path towards such a re-orientation of design approaches.

- Refocus design efforts from encouraging active exploration towards eliciting sensory exploration. A key element in this would be emphasizing aesthetic design. Interactive technology is capable of producing rich, varied and aesthetically pleasing interactivity, as illustrated by the Egg installation. This can add to children´s sensory exploration, inspire imaginative play and possibly also align with their engagement with the nature around the installations.
- Consider in what ways digital materials can become an abundant, rather than a scarce, resource. This can be done e.g. through implementing ways to collect digital traces in the environment (e.g. images and sounds), combining installations with mobile technology, or offering ways to reprogram the interactivity of installations.
- Take care to not overshadow nature, but instead integrate seamlessly with the low-key and low-spoken aesthetic qualities that nature features afford. Be sensitive to the sensory qualities of nature features and materials, so that nature is not used primarily as a resource for playing with the technology. Consider if technology can be a resource for exploring nature.
- Instead of focussing on creating interesting functionalities in singular installations, work with supporting children´s playful activity and mobility at large. Pay attention to placement. Develop an understanding for their possible moves and interactions with and around installations while roaming nature, in order to support a more fluent and ever-changing play flow where the digital materials are supportive to children´s overall exploration of nature and nature materials.

6.2.1 Limitations of study. An important limitation of the presented study is that the children were new to the digital installations. While the children were well acquainted with playing in both nature and playground settings and with using nature materials and playground equipment, the digital installations were alien to them. If the children had been acquainted also with the digital installations, it is likely that they would have required less time to investigate their functions, and potentially they could already have developed play activities for them that they could return to in recurring play [8]. However, the observations still show that active exploration is not in itself a very playful activity as has been argued in literature [37, 76].

It is also important to note that there already exist a variety of interactive play equipment for outdoor installation, and that this study was limited to a small number of installations. Hence, it is possible that other interactive installations could offer richer forms of engagement. However, the installations were all designed to offer open-ended interaction, they were placed to provide links to and inspire play in nature, and one of them (the Tube installation) was designed to be used together with nature materials. These design choices were deliberate attempts to support integration into nature-rich settings. This stands in contrast with how most standard outdoor interactive installations are designed to support competitive play and physical exertion [65]. Hence, the effects that were observed in this study are likely to be present, and even more pronounced, with more standard digital installations.

7 Conclusions

We performed a study of children's self-directed play in areas with access to both nature and digital installations. Our findings show that play with nature materials and standard play equipment on the one hand, and digital installations on the other, emerged in *different* ways. Most notably, imaginative play was observed emerging in close interaction with nature, while rule-based play emerged in relation to the digital installations. Furthermore, there was a difference in how the digital installations typically involved children in active exploration of their specific functions, whereas nature materials involved children in more joyous sensory engagement, including collecting and tasting. This engagement paved way for widely mobile and elaborate play episodes where children made use of their imagination.

Our study contributes with an empirically grounded analysis of how digital installations influence children's play in nature-rich environments. As discussed in the background, the health and pro-social benefits of play in nature have been observed with children engaging on their own terms. We propose a set of design opportunities for the design of future digital installations and other digital

technologies for nature-rich settings, that potentially can provide better integration with children's self-directed play in nature.

Acknowledgments

The authors wish to thank all teachers and children that joined and helped us carry out the study. The study was funded by Vinnova under grant 2018-04049.

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