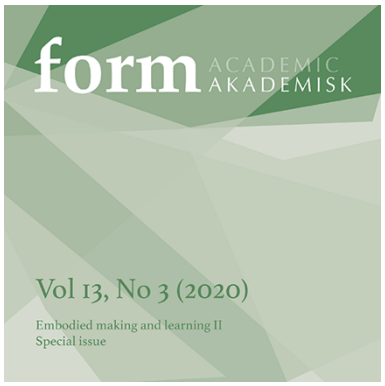

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Lovise Søyland
Doctoral Research fellow
Department of Visual and Performing Arts Education
University of South-Eastern Norway
lovise.soyland@usn.no

Children's sense-making through exploration

Grasping physical and virtual materialities

ABSTRACT
A child's sense-making is grounded in his or her bodily interactions with the environment and tied to the body's sensory experience. Digital technologies are being introduced into children's learning environments and they experience virtual materialities to a greater extent now ever before. This study aimed to uncover how young children make sense of the world through explorative touch interactions with physical and virtual materialities. Children's sense-making was studied through an explorative inquiry that was supported by video documentation. This article discusses how the combination of materials, digital technologies and experiences of different materialities offers new opportunities for explorative interaction, transforming and shaping children's experience of the world through joint sense-making. It also identifies how children's past experience of material touch is important for them in their process of grasping virtual materiality.

Keywords:
sense-making, touch interaction, virtual materiality, arts and crafts education, embodied cognition

INTRODUCTION

The sense of touch is crucial to human development (Field, 2001) and it is central to human experience (Jewitt & Leder Mackley, 2019, p. 91); however, it is "still one of the least studied and understood modalities" (Prescott & Dürr, 2016, p. 1). Despite this, the younger generation is called the "touch generation", because of its extensive use of touch devices (Nicholas, 2010, p. 6). Touch has been neglected in many fields (Jewitt & Leder Mackley, 2019, p. 92), and the role of touch perception has received less attention than visual and auditory cognition (Nicholas, 2010, p.1). In recent years, the embodied approach to cognition in studies documenting learning has gained traction (Bengtsson, 2013;

Gulliksen, 2017; Kiefer & Trumpp, 2012). The embodied cognition perspective holds that "cognition is grounded in bodily interactions with the environment and culture" and it is "tied to the body's sensory and motor system" (Fugate et al., 2018, p. 1; see also Shapiro, 2017). The dynamic coupling of the sensorimotor system with the environment during explorative tactile and haptic perceptions is key to a person's ability to make sense of the world (Mangen, 2016, pp. 464–465).

Our knowledge is directly related to our embodied experience of the material and physical environment. Such experiences are seen as being particularly central to the lives of young children. As researchers in the field of early childhood education (ECE) have stated: "Children's multisensory exploration of material, tangible objects in their physical surroundings is fundamental to their cognitive development" (Mangen et al., 2019, p. 236). Studies in the field of early childhood arts and crafts education confirm the importance of children's touch interaction with materials in their processes of sense-making (Carlsen, 2015; Fredriksen, 2011a; Waterhouse, 2013). Children develop experiential knowledge by interacting with their surroundings from an early age. They engage in explorative interactions to seek out multisensory input to enrich and support interpretation; the "creation of new meanings happens at the core of these explorative actions" (Fredriksen, 2011a, p. 299). Children's explorative processes with materials are seen as central in arts and crafts education, and these can provide potentials and opportunities for children's sense-making processes. Anthropologist Tim Ingold (2018) has argued that humans need upside down ways of exploring and grasping the world.

Our physical surroundings also consist of digital technologies, which, in this article is understood as tangible objects made of materials, while also being a medium and a tool. This implies that there is also a potential to use them in exploration. Digital technologies have been introduced into children's learning environments. The "rapid growth of digital technologies during the 21st century have paved the way for an upsurge in young children's play and learning" (Kucirkova et al., 2019, p. 3). In the Nordic countries particularly, educational institutions embrace technologies, such as touch devices (Bølgan, 2018), and Norway is at the top of the list of countries in Europe with the largest number of children that have access to touch devices (Letnes et al., 2016, p. 6). Consequently, to a greater extent, children experience virtual materialities in their surroundings.

Materiality refers to our perception and experience of materials; through interaction with our surroundings, we can experience its materialities (Ingold, 2007, p. 7). In this context, virtual materiality is understood as an illusion. It is made available through the software of a digital technology; for example, through our senses we can experience an object on a touch device that is not actually there (Søyland & Gulliksen, 2019, p. 4). This will be more thoroughly explained later in this article. Knowing that children are developing experiential knowledge through intensive interaction with their physical environment from an early age, this shift in the environment could potentially have an impact on how they explore, touch and make sense of the world.

Although touch has been neglected in many fields, Jewitt and Leder Mackley (2019) noted that "touch is at the centre of Human Computer Interaction (HCI) and computer sciences" (p. 91). An example of this type of study is from the ongoing IN-TOUCH (2016–2021) project led by Professor Carey Jewitt (https://in-touch-digital.com/). In this study, digital touch is broadly defined as touch that is digitally mediated, involving a range of technological domains, including haptic devices and virtual touch (Mitchell et al., 2019, p. 5). The study acknowledged how digital touch, and its possible mediation, are at the forefront of design students' thinking and making (Mitchell et al., 2019, p.8). This knowledge can mean that children's virtual touch, and its possible mediation, can also have a central role in their explorative process. Søndergaard (2013) studied how children conceptualise virtual materiality in computer games, and emphasised how, as a phenomenon, the physical and virtual is enacted differently, depending on the situation. Others have explored touch in artistic, multimodal and computer-based environments, stating how the haptic bridge the gap between the physical and the virtual (Stenslie, 2010). This knowledge is important in further studies of the meaning of virtual touch for children and how children make sense of virtual materiality.

Rich opportunities for interaction are necessary to facilitate children's exploration and sensory experiences (Fredriksen, 2011a). In education, there is a tendency to highlight measurable knowledge and "the effective production of pre-defined learning outcomes" (Biesta, 2013, p. 2). In my experience,

the introduction of digital technologies in children's learning environments can potentially enhance this type of learning. However, children's creative processes, such as handling a material through touching, sensing, knowing, feeling and thinking, is a complex way of exploring the world that is opposite to this tendency. The Norwegian National Framework Plan for Kindergartens emphasised that children are competent and active individuals who express themselves and learn through their bodies (Ministry of Education and Research [MER], 2017). The plan stipulates that "staff shall enable the children to explore, play, learn and create using digital forms of expression" (MER, 2017, p.45). This requires a practice that invites children to engage in active exploration through their bodies when creating, for example, artistic expressions using digital technologies in an environment (see Figure 1 for an example of what an artistic expression can look like). As an artist, researcher and teacher in arts and crafts education in Norwegian early childhood teacher education, I see it as my responsibility to contribute to defining what this explorative and creative practice can be and developing it.

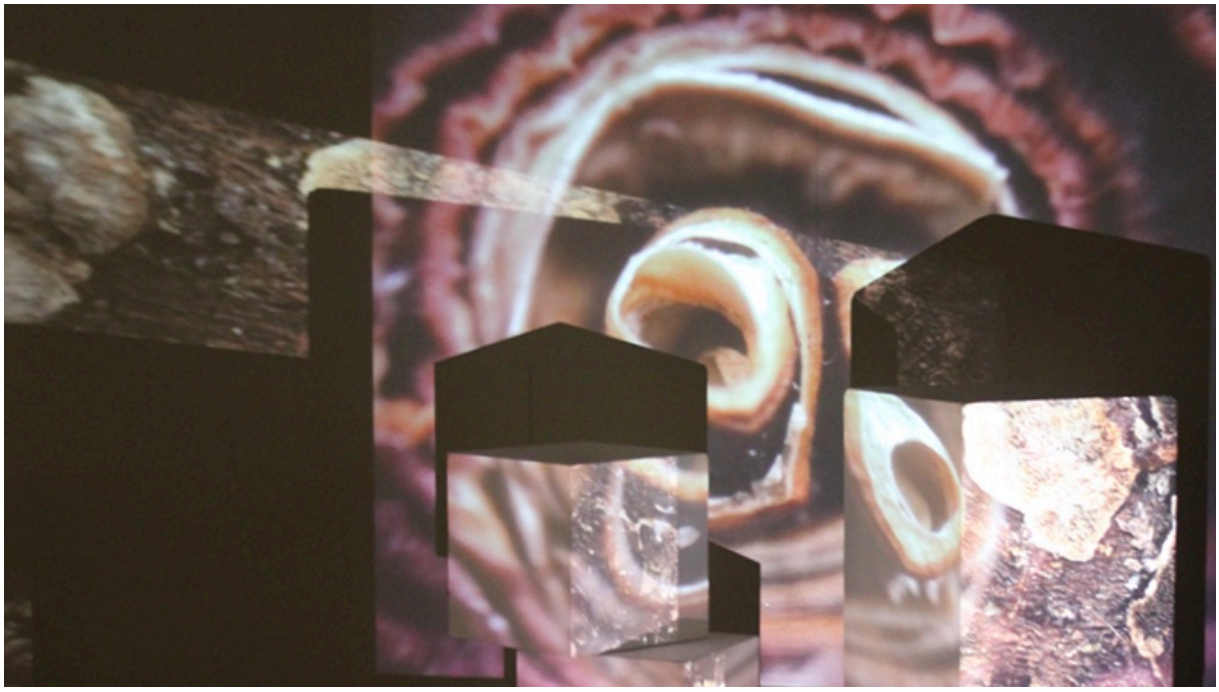

FIGURE 1. An artistic expression created in a room by projecting an image of a red onion into a physical environment consisting of material cubes. All photos in this article are by the author.

The introduction of digital technologies into children's learning environments brings challenges and opportunities. In a previous study of a picture book app for children, I identified the limitations related to a person's capacity for exploring and actively co-creating when interacting with the app (Søyland & Gulliksen, 2019). Several studies on children's sense-making processes with digital technologies have confirmed the need to move away from technical, instrumental and measurable skills and towards explorative, active processes (Bølgan, 2018; Letnes, 2014; Waterhouse, 2013). In this context, exploration is understood as a strategy used to make discoveries and identify new perspectives and artistic expressions. Exploration requires action; it is closely connected to play. Through exploration, children can understand more about the world, others and themselves.

However, children's sense-making through exploration of their material surroundings may also be facilitated by using digital technologies as a medium and a tool. This study aimed to answer the following research question: How do young children make sense of the world through explorative touch interactions with physical and virtual materialities? In this article, this question is discussed through a case study, which involves six young children and their kindergarten teacher. To explore this issue in depth, I observed these young children's touch interactions with, and exploration of, materials – such

as a dried red onion, a purloin flower, a buck skull and technologies – such as iPads, projectors and flashlights. This was done in a facilitated learning environment together with their kindergarten teacher. For this particular case, the discussion focuses on explorative touch and the tactile interactions between the children, the materials, the technologies, the environment and the adults in order to critically assess how these factors facilitate the children's sense-making.

EMBODIED COGNITION, SENSE-MAKING AND TOUCH

The perception phenomenology of Merleau-Ponty (1962) has inspired theoretical and empirical research in cognitive science, "especially into discussion of enactive and embodied conceptions of the mind" (Gallager, 2017, p. 9). Through material and social interactions, children get to know the manifold properties of their environments, as well as the capacities of their own bodies and minds (Fredriksen, 2011a). Children develop experiential knowledge through intensive interaction with their environment from an early age. Therefore, their material engagement is important. Young children interact more intensively with materials because they have more to learn than adults who have already gained these experiences.

In recent years, interest in embodied learning has increased (Bengtsson, 2013; Gulliksen, 2017; Moser, 2014). The theoretical framework of embodied learning stems from an epistemological tradition derived from Dewey (1934/2005) and Eisner (2002), as well as from the sociocultural perspective on learning (Vygotsky, 1978; Sawyer, 2014). This theoretical perspective has been supported and expanded by new knowledge from the rapidly developing neurosciences (Schilhab, 2017) and by research in the field of arts and crafts education (Gulliksen, 2017).

In this article, sense-making is understood as a person's active process of making sense through interacting with his or her environment. In such a process, cognition is directly linked to the person's ability to act, facilitated by the opportunities offered by the environment (Gibson, 1986, p. 127). Enactivism acknowledges how cognition functions as a person's active process of transforming the world into an environment that has meaning and value in and of itself (Thompson & Stapleton, 2008, p. 25). According to Nordtømme (2016), children's sense-making is situated, emerging through interaction with the materialities and conditions of their surroundings. Thus, children have access to the world through their sensory experiences of their environment, and perception and interaction are inseparable in the process of sense-making. In this process, their sense-making emerges from the "meetings" between their past and new experiences (Fredriksen, 2011b, p.77).

There is also a social dimension to children's sense-making. When a group of children are exploring, for example, materials, their processes involve feelings, embodied knowledge and communicating with each other. Di Paolo and Thompson (2017, p. 75) used the term "participatory sense-making", meaning that sense-making can be shared among the interactors and be experienced, to various degrees, from the orientation of individual sense-making to joint sense-making. Through joint sense-making, children can experience something that would not be possible on their own.

We experience our environment and make sense through our bodily senses of touch, sight, smell and taste. The sense of touch is often being associated with fingers and hands, but touch is plural and it is "a conceptual umbrella covering a wide field of experiences than a sense" (Stenslie, 2010, p. 85). We experience touch through a combination of tactile perceptions, such as when someone touches our skin, haptic perceptions, such as when I grasp someone's hand, and our position when we move in a space (Søyland & Gulliksen, 2019, pp. 2–3).

A person receives sensory information through many types of receptors; this results in a multimodal sensory experience. Implicit memory evokes and utilises emotions without our conscious attention, colouring our sensory experiences and focusing our attention towards certain aspects of our senses, and our declarative memory re-enacts past perceptions in episodic memory (Purves, 2012, pp. 698–699 in Søyland & Gulliksen, 2019, p. 3). For example, when a child reaches out and touches the wool of a sheep (see Figure 2), memories evoke and utilise emotions, influencing the experience and the sensory information the child perceives in the context (Maiese, 2017, p. 231; Willems, 2017, p. 35).

When a child is remembering his/her past interactions, it "involves a making present again, although in a modified sense" (Shapiro, 2017, p. 10).

FIGURE 2. A photo of wool.

Imagination is also a key factor in children's sense-making process. Memories and emotions are closely linked to imagination because each case of perception involves the child imagining, for example, how it would feel to grasp and smell the wool of a sheep (Gibbs, 2006, p. 64). Children's new understanding emerges from combining their past and new experience (Fredriksen, 2011b, p.77). Memories and imagination involve making the past and present sensible in a moment (Willems, 2017, p. 35). Our imagination is also linked to brain maps of space developed through our past experiences, and it is an important factor in understanding ourselves in relation to our environment (Groh, 2014, p. 5).

MATERIALS, DIGITAL TECHNOLOGIES AND MATERIALITIES

Density, weight and form are some of the properties of a material. However, material properties cannot be identified as specific characteristics; rather, they are understood through relationships, for example, a person's tactile interaction with a material. Ingold (2013, p, 6) noted: "Materials think in us, as we think through them" in the "fluxes and flows of the materials with which we work". Ingold (2011) described how the material world, which includes physical objects, is "constantly inspiring us, challenging us, telling us things" (p. xii). He described how materials affect us when we handle them, making an imprint on and changing us.

Ingold (2007) defined materials as tangible, the stuff they are made of; materiality refers to our perception and our experience (p. 7). I build on an understanding that a material can also be intangible; for example, light is electromagnetic radiation, i.e. a physical phenomenon, which, in some cases, we can feel as heat on our skin while at other times we can only experience through sight. Our surroundings have a materiality that we can perceive through our senses. In the context of the study discussed in this article, physical materiality is defined as the child's perception and experience of a material, such as light from a flashlight and wool from a sheep.

Digital technologies are physical objects made of materials, while also being a medium –meaning a channel through which we can experience something – and a tool that, through interaction, we can use to influence or change something.

Gibson (1986, p. 41) described objects like tools as "a sort of extension of the hand, almost an attachment to it or a part of the user's own body". Through interaction, a physical object, such as a tool, is in close relation to our body. A touch device is made of materials; thus, paradoxically, we can touch and manipulate objects on a screen without actually touching them and see objects that are not actually there. I refer to this aspect as virtual materiality, an illusion that has no physical properties (see also, Søyland & Gulliksen, 2019, pp. 3–4). We can also experience an illusion of an object, a virtual materiality, through a projector. Virtual objects can be experienced through sight on a screen and through sight in our surroundings, for example by walking around them in a room. An example of this is a photo of the buck skull on a touch device or a projection of a buck skull, which, in this study, is defined as a virtual object (see Figure 3). Virtual materiality can also be experienced as something abstract, such as colour and lines.

FIGURE 3. A photograph of an image of a buck skull projected into a room

Virtual materiality is made available through the software of digital technology and, for example, by light from a projection. The sensory information/impressions are translated into electrical signals and interpreted by a person. The interpretation of virtual materiality is linked to a person's past experience, his or her implicit and declarative memory (Søyland & Gulliksen, 2019, p.7), and it emerges from the ´meeting´ between a person's past and the new experience. A touch device has a tangible surface, which can be experienced through tactile and haptic perceptions, and an illusionary virtual materiality that can be experienced through sight. These experiences can occur simultaneously.

Ingold (2017) asked if eyesight "could be as haptic" as manual touch (p. 3). Fugate et al. (2018) argued that:

> …embodied cognition theory proposes that knowledge is re-enacted (i.e., simulated) through the perceptual and sensory systems (e.g., auditory, visual, motor, and somatosensory) such that thinking about an action will evoke the same visual stimuli, motor movement, and tactile sensations that occur during the act itself. (pp. 1–2)

In touching the surface of wool, "the experience is captured by the sensory and perceptual systems and can later be used to recreate (through simulation) the experience without the actual stimulus" (Fugate et al., 2018, pp. 1–2). Therefore, children can recreate the feeling of touching wool when they experience it as a virtual materiality on the surface of a touch device or the wall onto which a photo is projected.

The terms, physical materiality and virtual materiality, are necessary to explore and describe the differences in how these materialities can be grasped, and what happen when these materialities occur simultaneously and add something to the children's experiences. Our interaction with and our perception of different materialities, such as light from a flashlight and a virtual object projected into a room, make them transformable in similar ways like a material in an explorative and creative process. The different materialities can also be understood as different layers that we perceive through our perceptions. For example, we can simultaneously perceive virtual materiality, materiality of light from a flashlight and materiality of a wall in a room.

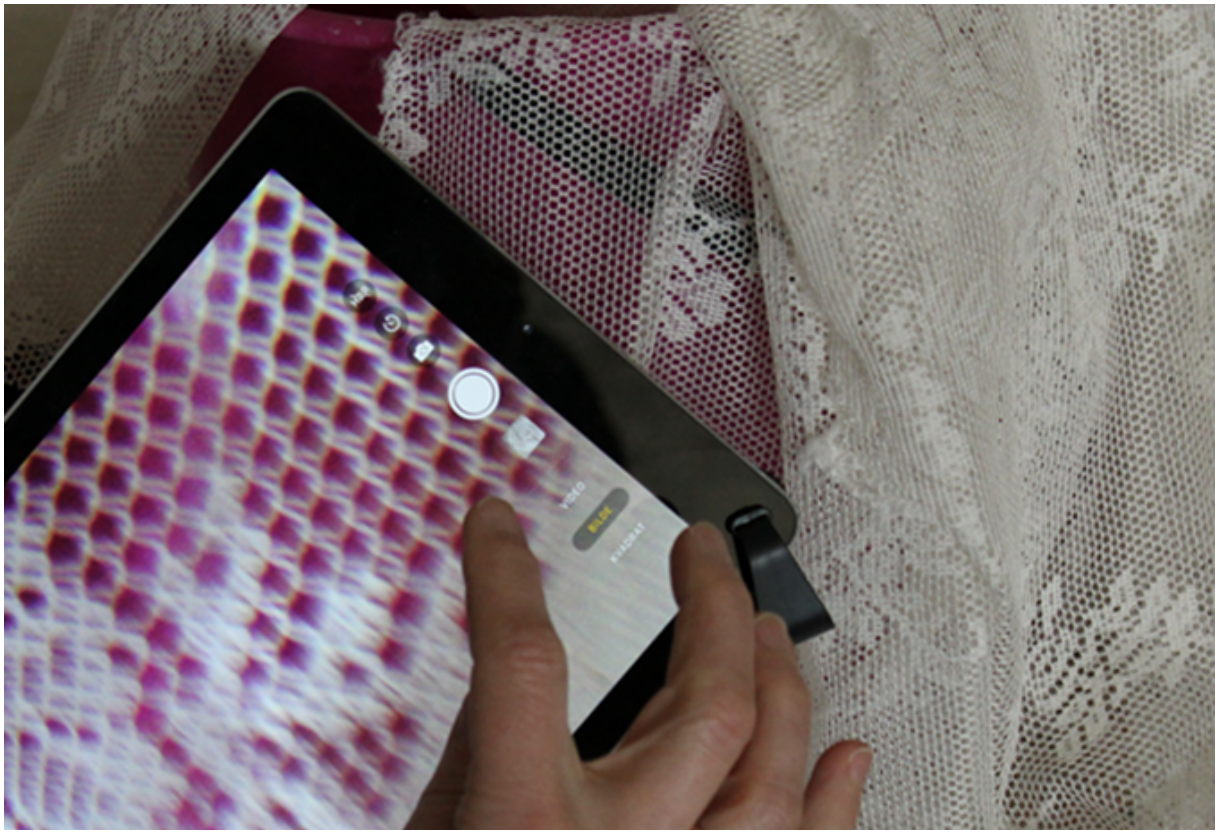

FIGURE 4. Digital technology can transform what we perceive

I build on Gibson's (1986, p. 127) idea of affordances, which, in this context, is understood as qualities of a particular material, digital technology or environment that allow the child to perform an action. The term implies that the environment provides resistances and abilities for children through their actions, whether the material is tangible or not. Affordances may be conceived of as relations, or interactions, between abilities of children and features of materials, digital technology or environments; thus, they are "part of the act of perception" (Chemero, 2010, p. 186). Merleau-Ponty (1962) described how

sensory information can be perceived through the use of a tool as part of our perceptual field, like a blind man's cane (pp. 146–152). Ihde (1990) defined the relationship between human beings and digital technologies as embodiment relations, since such objects seem to become part of our embodiment (pp. 23–27). Children embody digital technology and experience things that would otherwise be impossible. This combination of medium and tool can expand our awareness of them as "phenomena which lie beyond human sensory capacities" (Ihde, 2012, p. 376) as they transform what they are able to perceive. In this way, virtual materiality can be both a representation of the world and a materiality that we would not be able to perceive without technology (see Figure 4). Time, or the duration of an activity, is closely connected to this concept as an active and dynamic element in children's explorative processes. Digital technologies will also affect children's experience of time and space, providing them with a structure for sensory perception in the process of sense-making (Elleström, 2011, p. 36). In this way, there is a potential for children's interaction with digital technologies to expand their exploration and experience of the world.

METHOD

Children's sense-making processes emerge in complex and nonlinear ways. As an adult and a researcher, it is difficult to know what a child feels and thinks through their explorative interactions, and I can only imagine and suggest what goes on in a child's experience. Explorative inquiry is a form of arts-based research that draws inspiration, concepts and processes from the arts in order to cope with complexities and express understandings that otherwise would be ineffable (Dyrssen, 2010, p. 224; Barone & Eisner, 2012, p. 1).

Explorative inquiry supported by video documentation gave me the opportunity to explore and interact with the children. To understand the complexity of children's sense-making, I joined the children in their exploration and actively used my subjectivity, senses, memories and emotions (Bresler, 2006). I positioned myself as an a/r/tographer (Springgay et al., 2008), taking on the identities of artist, researcher and teacher. I was also inspired by ideas from sensory ethnography (Pink, 2015). Sensory ethnography is an embodied form of ethnography that moves beyond the text and the visual to the tacit, unspoken and non-verbal in experience (Pink, 2015, pp. 26–31).Through the combination of explorative-, a/r/tographical and sensory ethnographical inquiry, I was able to generate rich and complex data by joining the children in their explorations.

Six children, aged five and six, and their kindergarten teacher participated in the study. The project was approved by the Norwegian Centre for Research Data (NSD), and a formal written invitation, including a consent form, for participation was given to the children's parents and the kindergarten teacher. The teacher and the parents of the six children responded positively and gave their permission for the children to take part in this study. I spoke with the children about the project, and I told them that their participation was voluntary. Before beginning the exploration, I clarified the roles that I and the teacher would be playing.

The generation of data was conducted over the course of three days. The children were divided into two groups of three. On day one, I met the two groups separately in their kindergarten. Throughout the day, I became familiar with the children, and I got to know some of their experiences with materials and digital technologies to further tailor the study. On days two and three, the two groups of children were invited into a large-scale project room at the university, which I had preorganised for material exploration. The room was arranged to invite the children to engage in explorative interactions with different digital technologies, such as iPads, projectors, macro lenses and flashlights, and physical materials, such as leaves, a thorny twig and a buck skull (see Figure 5). In this process, I had to plan as an a/r/tographer. Thus, I had to decide which materials and technologies should be included, how to invite the children to participate in exploratory processes and how to place the video cameras to capture the children's interactions. There was a risk that the children would understand the project room as an exhibition, carefully arranged by an artist, wherein they were not allowed to touch and move things. Therefore, before entering the room, I spoke with the children about what they could and could not do

in the room; for example, they could touch the materials and move them, but there were still some materials, such as glass, that they had to be careful with.

FIGURE 5. The arranged large-scale project room and a close up of some of the materials available in the room.

The exploration with each group on days two and three lasted approximately two hours, including a break. Throughout these sessions, I was explorative and present as a teacher and an artist, paying attention and joining in the children's interactions. In some interactions, I had to turn my attention towards my identity as a researcher and forget about being a teacher, such as when something interesting occurred in one of the children's processes and I had to let another child, who wanted my attention, wait.

I documented the exploration by using a headband camera, placed on me, and an overview camera of the room. I also used a camera to take photos of important events. The children also took photos and videos. Through the participatory explorations, I could also pay attention to the children's facial expressions, bodily movements and sounds. The observations were written down on the same day, immediately after the exploration. Video documentation was used as a supplement to these observations and notes. The total amount of empirical material collected was six hours of video documentation, 89 photos taken by me and 500 photos and 20 short videos taken by the children.
When transcribing the video, the focus was to capture rich and complex experiences through the children's facial expressions, gestures, movements and verbal utterances by using my identity as an a/r/tographer. An initial overview analysis was made during the transcription. The raw data included a transcribed video, screenshots from the video, photos taken by me and the children and my own observational notes. The data were combined into a 70-page document, first arranged chronologically. The analysis focused on the children's sense-making, interpreted through their expressions of emotion during their explorative touch interactions, whether there were sounds of amazement or facial expressions of surprise or discovery.

At first, I focused on the interactions with the five materials: leaves, a thorny twig, a buck skull, a piece of wood and a purloin flower. I studied what the children touched, how they moved and what occupied their attention. I went back and studied the video clips in depth, recalling my memories of individual moments, such as when the children made discoveries. In a further process of analysis, I found it especially interesting to study three material interactions: (1) leaves, (2) a thorny twig and (3) a buck skull in conjunction with a virtual iPad button. These interactions were then developed into thick descriptions (Stake, 2010), short moments described using poetic language. The descriptions were supported and complemented by photo collages that I made using the photos taken by the children and me or captured from the videos. The analysis was concluded by identifying three groups of themes: (1) materiality, movement and touching with light, (2) virtual materiality and touch and (3) materiality, exploration and experience.

THICK DESCRIPTIONS

This section presents a discussion of the thick descriptions and photo collages (see Figure 6-Figure 10) of the three chosen material interactions: (1) leaves, (2) a thorny twig and (3) a buck skull in conjunction with a virtual iPad button.

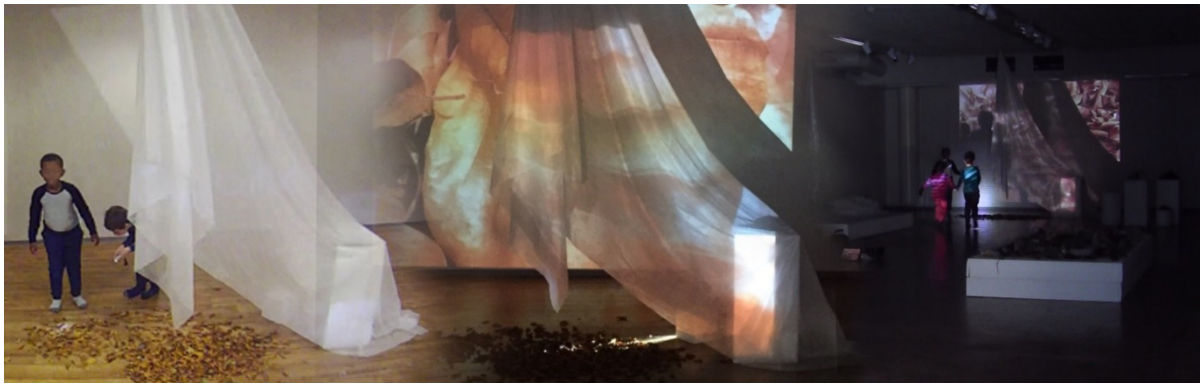

FIGURE 6. Interacting with the physical leaves and the projection.

Leaves

Before this interaction, the children took the initiative to use the flashlights that were available in the room.

> The children are standing together at the narrow end of the room, holding flashlights. At the other end, a transparent piece of white cloth hangs from the ceiling, and there is a pile of dried leaves on the floor. I suggest that we turn off the light. With eager voices, the children agree. I turn it off. A photo of virtual leaves shines from the iPad via the projector to where the cloth hangs. When the light is turned off, the room is transformed. The children make bodily gestures and sounds, uttering words of amazement: "Wow!" The children run together towards the cloth and the projection. All three of them stop in the middle of the room by the iPad and projector. One of the children asks, "What is this?" Another says in an eager voice, "It is leaves, it is leaves, come on". The children move around the room, using their flashlights to create fluid spots and lines on the materials in the room and on the projection. The light is mixing with the surface of the room, the materials, and the virtual leaves. The children move their bodies, interacting with the light, which creates fluid shadows and expressions in the room. The children move fast and make sounds: they are enjoying themselves. They stop between the wall, the pile of leaves and the cloth.
>
> One boy sits down by the leaves. He grabs a handful, slowly squeezing them between the fingers of his left hand while lighting them with the flashlight in his right. After a while, the same boy moves his flashlight from left to right, creating lines of light on the virtual leaves. For a while, he holds the flashlight still, then brings it closer to the virtual leaves and makes a large spot of bright light within the projection. He stands still for a moment, looking at the spot. One of the children giggles; he is enjoying what he is doing. The other two children also make excited sounds. The children move to the other end of the room.
>
> The children are again gathered around the iPad and projector. One of them asks how the photo of the leaves can be transported from the iPad into the room. Another child blocks the light from the projection with his hand. Afterwards, he lies down on the floor in front of the projector. The light from the virtual leaves hits his body. "Look at me, look at me!" he shouts. His stomach shines with white, orange and reddish hues, and the children utter sounds of amazement. When the child moves from one hip to the other in the multi-coloured light, the whole room changes. The light is reflected on the floor, and a giant shadow of the boy moves around the room. The other two children are quiet, attentively watching in silent astonishment.
>
> The children head again for the cloth and the projection with their flashlights in hand, expressing excitement. They stop in front of the wall on which the virtual leaves are projected. Two of the children shout, "I am big, I am big", while they look at their shadows. They move their bodies in different ways in front of the projection, as if dancing, and different shadows appear as they block the light. They use their flashlights to shine light into the projection and onto their own shadows. Fluid expressions appear in the

room when they do this. The expression of the room changes as the children use their hands and feet to arrange the leaves in different ways. One of them slides on his hip into the pile of leaves.

FIGURE 7. The expression of the room changes

FIGURE 8. Interacting with a thorny twig.

A thorny twig

Two children move around a podium with different materials on it. They express verbally that they can identify some of the materials and try to lift them with their hands. Suddenly, one child turns his attention to a thorny twig. He settles down in front of it, slowly leans his body forward and stretches his hand out. His shoulders are tilted forwards, his arms hug close to his body and he wrinkles his forehead while leaning even closer to the thorny twig. He gently touches the tip of the thorn with one finger. When his finger hits the tip, he pulls his hand away quickly and exclaims, "Ouch!" Another child looks in the boy's direction and moves towards him. Their kindergarten teacher comes over, too. When she leans forward to touch the thorn, the boy looks at her face before looking at the thorn again. They both stretch their arms forward and gently touch the thorny twig with their fingertips. Again, the boy quickly pulls his hand away from the thorn, and his face breaks into a broad smile. He shouts in an eager voice, "It is not, it is not...!" The other child has now come over. Carefully, she leans forward and touches the thorny twig.

The children find the iPads. They hold them in their hands, some needing help to hold them still. They move closer to the thorny twig, photographing it. They switch their focus between the materials and the screen. Suddenly, one child makes an eager sound when photographing the thorny twig and shouts, "Oh! It is different". The child expresses how the materiality changes from the physical to the screen.

One child's photo of the thorny twig is projected onto the ceiling of the room. A boy jumps and stretches his hands in the air, saying, "Ouch!" and "I am watching television". I move the projection to the wall so that he can reach it. The virtual thorny twig hits the other materials and the surface of the room. The boy expresses astonishment as he enters the space with its different materialities and says,

"Wow, cool!" He runs to the podium where the materials are and tries to pick up the thorny twig. He says that he will bring it over to the projection of the thorny twig. However, he gives up, because it pricks him and he cannot hold it. He runs to the wall where the virtual thorn is projected. He jumps up and down, moves along the wall and "touches" the virtual thorn, repeating, "Ouch!" He uses both hands and moves his body as if he is going to pull the virtual thorn off the wall. He makes sounds as if he is really using his muscles. At the same time, he plays and jokes. One of the other children moves slowly towards the virtual thorn. Carefully, she puts her hand on the wall and touches it.

FIGURE 9. Interacting with the virtual thorn.

A buck skull in conjunction with a virtual iPad button

The children are occupied with the buck skull and are exploring it in different ways, touching its teeth and lighting up the inside. One child picks up the buck skull from the podium, videos it and projects the video into the room (I did not suggest this to the children; I help him with the iPad and the projection). The virtual button for "video mode" on the iPad is projected onto the room. He runs to the virtual button and jumps up and down while "tapping the virtual button". The other two children come over and one of them jumps and "pushes the virtual button", too. The two children repeat this, many times. The third child stands for a long time observing what is happening before she joins the game. I play along with the children's initiative and push the button on the iPad along with the children. They make joyful gestures. The children push the virtual button 54 times.

The buck skull video is projected onto the cloth and one of the boys moves in the direction of it. He turns around on his own axis, making scary howling sounds. The boy goes inside the hanging cloth, stretching his arms out and moving around, continuing to make scary sounds. It is as if he has created an imaginative world. The child tells his kindergarten teacher to move the flashlight back and forth across the room; it creates fluid expressions and the boy moves and interacts with it so that he becomes part of the expression. The child continues to move and make howling sounds for a long time.

FIGURE 10. Interacting with a buck skull in conjunction with a virtual iPad button.

ANALYSIS AND DISCUSSION

In the discussion presented in this section, I focus on the three groups of themes involving children's sense-making: (1) materiality, movement and touching with light, (2) virtual materiality and touch and (3) materiality, exploration and experience.

Materiality, movement and touching with light

When I turned off the light in the setting with the projected leaves and the children experienced the different materialities in the room, they made bodily gestures and sounds, uttering words of amazement. First, they moved together in the room, producing fluid spots and lines on the materials and into the virtual materiality using flashlights. They explored the light as it interacted with different types of materialities, and the whole room changed while they made spontaneous bodily and artistic expressions. It was as if they made new discoveries about how they could manipulate, influence and transform the room, thereby experiencing the fluidity of the materialities.

The children explored and asked questions about how the leaves could be projected into the room. When they explored the projection, one of the children laid down in front of it, and the light and the virtual materiality from the projection hit his body. The children reacted as if they had made a great discovery. Using gestures and words, the boy expressed that he was aware of the change on the surface to his own body while he rolled from one hip to the other. The children discovered what occurred when the projection hit their bodies. The experience of virtual materiality and light from the projection became something they could play with through moving, as if dancing, while making fluid and shifting shadows. The different materialities that occurred through the children's interactions offered a spatial potential that they exploited.

I understand their first experience as a process of sense-making wherein they explored as a way of "growing" into understanding. This is in line with Ingold (2011), who described how people can be inspired, challenged and compelled to develop understanding through exploring materials and tools. The children were attentive to each other's explorations and movements; when one child moved in a certain way, the other children responded to it. Examples of this are when they moved their bodies in different ways in front of the projection of the leaves and when they used their hands and feet to arrange the physical leaves in different ways. They explored together in a joint process of sense-making—making discoveries together that would not be possible on their own. The phenomena that I discovered is in agreement with how Di Paolo and Thompson (2017, p. 75) acknowledged that sense-making can be joint (shared).

One of the children stopped by the wall and moved his flashlight gently from left to right, creating lines of light into the virtual materiality of leaves, before he held it still and placed a large spot of bright light within the projected image of leaves. It was an attentive moment, like "time stood still", while he stopped and observed the change through the combination of light from the flashlight and the projected image. It was almost as if he "touched" the virtual materiality with the materiality of light.
Through the boy's interaction, the flashlight became an experientially transparent extension of his hand and his body. This demonstrates the intimate relationship between the body and tools that Gibson (1986) described. The boy's touching can be understood as a re-enactment of his past experience of touching, which is in line with Fugate et al.'s (2018, pp. 1–2) description of how knowledge can be re-enacted through the perceptual and sensory system. The boy's past experience of movement and tactile and haptic touch could potentially evoke tactile-like emotions and perceptions in this new context (Maiese, 2017, p. 231). Like Shapiro (2017, p. 10) described, re-enactment of past perception occurs in a modified sense; in this context, I understand the boy's touching with light as being adjusted in comparison to grasping physical leaves.

The same boy also sat down by the pile of leaves and grabbed some of them, slowly squeezing them between his fingers while lighting them. I interpret the boy's squeezing as an exploration of the physical materials, just as he explored the virtual materiality of the leaves with the light from the flashlight. The boy's sense-making was influenced by the specific affordances offered by the environment (Gibson, 1986), and it emerged through interactions with the materialities and condition of the surroundings (Nordtømme, 2016). Fredriksen (2011a) argued that children make sense and

understand the manifold properties of their environment through material and social interactions. This facilitated environment, which included digital technologies, offered manifold properties, like the intangible light, that the children used to manipulate and change their surroundings through movement, mixing physical and virtual materiality in their experiences and the process of sense-making.

Virtual materiality and touch

Two of the children exhibited fascination, making facial and bodily gestures of amazement, in their interaction with the thorny twig. The children expressed curiosity and excitement before actually touching it. They explored it attentively and carefully with their fingers, and I understood their sense-making process as a sense of enchantment towards the thorns, which were touchable but still a bit dangerous.

When the twig was projected into the room, the mood in the group was more energetic than it was for the careful exploration of the physical thorny twig. All three children were present, but one boy led the way. The projection of the twig offered different affordances and proportions than the material thorny twig that the boy could not hold in his hands. The boy "touched" the virtual materiality of the thorny twig by stroking his hand on the wall displaying the projection. His touch was real, but what he touched was an illusion. He laughed, playing and pretending that the thorn pricked him. The boy also jumped, trying to reach the virtual thorny twig on the ceiling, moving his body as if trying to pull it off the wall. Without relevant previous experience, the two-dimensional illusion of the three-dimensional twig would not make sense in the boy's exploration. One of the other three children, a girl, had a more careful approach to the virtual materiality of the thorny twig. She moved slowly towards it and carefully put her hand on the wall to "touch it." She had another approach to exploring. It was as if she knew that it could not prick, but could she be certain?

FIGURE 11. One of the children's photos of the thorny twig projected onto the wall

Thus, the virtual materiality of the twig may be understood as a visual representation of a physical twig. The children used their past experience of touching the physical twig to play and to create a new experience of touch while interacting with the virtual materiality. In line with Fugate et al. (2018, pp. 1–2), I understand this as the children re-enacting their embodied knowledge through the perceptual and sensory system. In their exploration and play, they used their emotions and imaginations, pretending that the virtual materiality of the thorny twig could prick, be grasped and be pulled from the wall. In line with Gibbs (2006, p. 64), this demonstrates how emotions and imagination are the basis for their touch

perception. This imagination is also linked to brain maps of space (Groh, 2014, p. 5), developed through their past experiences, and it is an important factor in their sense-making process and how they develop an understanding of themselves in relation to their environment. This instance identifies how past experiences of material touch are important for being able to explore and make sense of virtual materiality. In their process of sense-making, the children had a similar approach to the physical twig when they expressed their emotions and excitement before they actually touched it.

The virtual thorny twig may not be perceived merely as a representation. Through words, sounds and bodily expressions, the children expressed how they experienced a change in the materiality from the physical twig to the virtual materiality of the twig projected on the wall (see Figure 11).
When the children moved inside the projection of the twig and I moved the projection slowly along the wall, sometimes the projected virtual materiality changed from being perceivable as a representation to being blurry colours and abstracted shapes, like an abstract painting in motion (see Figure 12).

FIGURE 12. Virtual materiality of a thorny twig in motion.

In line with Ihde (2012), who argued that digital technologies can expand beyond a person's sensory capacities, through interaction, the technology transformed and changed how the children perceived the world, offering something different in their process of sense-making (p. 376). Moreover, digital technologies can shape the familiar, like a material thorny twig, in different ways, turn it upside down to enter a different territory, an explorative way to relate to the world (cf. Ingold, 2018).

When one of the children took the initiative to video the buck skull, the iPad application for videos and photos was projected onto the wall. The children became aware of this and started to play a game where they jumped to "press" the virtual button on the wall "to take photos". I became part of their play when I pressed the iPad button simultaneously. This is interesting, because the button I pressed was actually a virtual button, too; it was a representation of a button with touch sensors. Thus, it was an illusion of physical substance (materiality). However, it is physical in way that is different from the one projected onto the wall. The children's touching on the wall was a real action, but what they touched was an illusion. The children expressed amazement when their virtual button "functioned," although they understood that it was caused by my pressing the iPad button.

This identifies how children also take past experiences of touch interaction—such as pushing buttons on an iPad—into their play to make sense and create new experiences in their environment. We explored, played and made discoveries together. We made sense together and found opportunities

to interact offered by this environment that I, as an a/r/tographer, had not imagined in advance. In other words, I learned from the children through joint sense-making.

Materiality, exploration and experience

When the boy moved his body and arms inside the cloth that had a buck skull projected onto it, it was as if he used his past experience of producing fluid expressions, earlier in the day, to set different materialities into play with each other. By touching and moving the cloth, which was tangible, he also transformed the experience of the virtual materiality and the materiality of light, which is intangible.
He moved around inside the cloth, and the virtual materiality was infused with the physical while he made howling sounds. He created an imaginative world and became a scary figure, like a ghost (see Figure 13). It is possible that the skull, perhaps as a symbol for something scary, affected the boy; this proposition could have been further explored. In this instance, the two other children observed what was happening, but they did not participate in the interaction. I was attentively present, observing, and I was in charge of the projector.

The boy asked his kindergarten teacher to move the light of a flashlight back and forth into the other materialities while he continued his movements and play. The idea and initiative to involve the teacher in the process built on his past experience of exploring materialities and his imagination about what expressions the requested actions could create. This is in agreement with Gibbs (2006, p. 64), who explained how past experience and emotions are closely linked to imagination. Artistic expressions occurred when the boy moved the cloth, and the virtual materiality mixed with the surface of his body and the moving light from the flashlight. His imagination and the transformation of the materialities became an expression he used to stage his actions. Together with his teacher and me, the boy explored the affordances of actions and materialities in his environment through his perceptual and actionable capacities. Through joint interaction, the affordances became part of the act of perception (Chemero, 2010, p. 186).

FIGURE 13. The boy moving inside the cloth with a virtual buck skull projected onto it.

Initially, the challenges of introducing digital technologies into a children's learning environment was highlighted, a change which can enhance the instrumental and effective approaches to learning in education, and the tendency for children to experience virtual materialities to a greater extent than ever before. It is easy to argue that touch is the most direct impact children have on their explorations of their environment's manifold properties, and that their material engagement is crucial to their sensory experiences and sense-making. However, this kind of educational and artistically arranged environment granted the children more opportunities for exploration and touch interaction than the materials or digital technologies could offer alone. The children were also brought into a setting that offered an open invitation to participate in joint sense-making, to explore the environment together with each other and the adults. The children made sense through their interactions, artistic expressions, discoveries and imagination. The environment offered the children opportunities, from exploring a thorny twig by gently touching it with their fingertips to experiencing a huge, projected thorny twig in a room that could be played with and "touched". It offered the potential to experience and explore the change in materiality, when the projection of the twig turned virtual with blurry shapes, colours and lines—like an abstract painting in motion.

CONCLUSION

The embodied cognition theory offers a theoretical framework for understanding children's sense-making in their interactions with their surroundings. The study discussed in this article identified how children make sense through transforming and shaping their experience of the material world by using digital technologies as a medium and a tool in their explorations. Through joint sense-making and interaction, we—the children and adults (myself and the kindergarten teacher)—transformed the environment into a space that had meaning and value and that could expand our experience of the world. We built on each other's discoveries, bodily movements, material movement, sounds and imaginations. The children were offered rich opportunities to influence their surroundings, to make artistic expressions, to make their own choices in relationship to and in interaction with different materialities, each other and the adults, and to be explorative and autonomous. These qualities are all crucial in the process of sense-making (Thompson & Stapleton, 2008, p. 25). Ingold's study (2013) identified that materials "think in us" (p. 6); I argue that the experience of virtual materiality in this kind of environment can also "think in children", even though it is not tangible like most materials. The study also identified how important the children's past experience of material touch is to grasp virtual materiality, even though virtual materiality is an illusion. Today, children experience a different learning environment than children did just a few years ago. It is crucial that children be able to track virtual materiality back into their experience of physical materiality and understand the differences. This understanding is especially important for kindergarten teachers and early childhood teacher educators to consider in order to ensure that children are exposed to the rich possibilities of sensory experience at an early age and to give children the opportunity to explore, combine and grasp different materialities. The study identified a practice that invites children to express themselves through their bodies, exploring and creating artistic expressions by using digital technologies as a medium and a tool in a material environment.

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