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Lovise Søyland

Grasping materialities

Making sense through explorative touch interactions with materials and digital technologies

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If you touch something (it is likely) someone will feel it.

If you feel something (it is likely) someone will be touched.

Rick Valicenti

Abstract

Our senses are deeply ingrained in the materiality of the world, and our embodied minds are shaped by touch interactions with the environment. Arts and crafts education is characterized by explorative, creative processes wherein children's and adults' tactile and haptic experiences are central to their interactions with various materials and technologies. In recent years, there has been a digitalization of materiality in educational settings. This digitalization involves a change from using physical materials in early childhood education (ECE) and in early childhood teacher education (ECTE) to those based in the virtual realm. There has also been renewed interest in the connection between embodied action and cognition in recent years in studies documenting learning as an embodied process. However, few empirical studies on embodied cognition have been conducted to study the sensorial and explorative aspects of interaction with the materiality of digital technologies. The overall research question of this doctoral dissertation is: *How can explorative touch interactions with physical and virtual materialities facilitate processes of sense-making?* The conceptual framework of this dissertation is related to the theory of embodied cognition. The theory acknowledges that we develop knowledge and make sense through our embodied minds, which are rooted in the bodies' sensory experience. This study applies an arts-based research (ABR) methodology in order to investigate haptic and tactile experiences. The study draws inspiration from sensory ethnography and a/r/tography and is supported by video documentation.

Through three case studies, sense-making in tactile and haptic interaction with physical and virtual materialities was studied. The case studies were explored using four sub-questions: *What happens when we*[1] *open up to experimental and unforeseen processes that transform physical and digital materials and phenomena into creative processes? How is touch interaction with a picturebook app facilitating or limiting sense-making? How do young children make sense of the world through explorative touch interactions with physical and virtual materialities? How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations?* The first case involved ECTE students' explorations in an arts and crafts teaching project. The study was conducted at the University of South-Eastern Norway. The students were invited to explore and experiment with different materials and technologies in a project room. The aim was to examine

[1] The authors: Ann-Hege Lorvik Waterhouse, Lovise Søyland, and Kari Carlsen.

what happens in the manipulations of materiality throughout the creative process. The second case involved an in-depth explorative inquiry of my own touch interactions with a picturebook app. The app was selected because of its innovative use of virtual reality and facilitation of explorative interaction through touch. The third case examined children's sense-making and exploration of physical and virtual materialities during a creative process. Similar to the first case, the children were invited to explore and interact with different materials and technologies in an arranged large-scale project room. The aim was to uncover how young children make sense of the world through explorative touch interactions with physical and virtual materialities.

During the study, six main themes were identified that have theoretical and practical implications for education. These themes are: (1) Tactile and haptic dimensions of materiality bridge understanding of the material to the virtual, (2) Emotions and imagination are embodied sense-making faculties during interaction with virtual materialities, (3) Virtual materiality can initiate new discoveries and shape the experience of the material world, (4) Digital technologies and strategies that provide opportunities for co-creation and exploration are essential to sense-making, (5) Joint exploration influences the process of sense-making with digital technologies in interaction with the physical environment, (6) Haptic visuality and artistic forms of exploration can deepen understanding of sense-making and touch interaction.

Keywords: Sense-making, touch interaction, virtual materiality, haptic visuality, arts and crafts education, early childhood education, embodied cognition

Abstract Norwegian

Våre sanser er dypt sammenvevd i omgivelsenes materialiteter og vår kroppslig forankrede kognisjon formes av taktil og haptisk interaksjon med omgivelsene. Forming (Arts and crafts) og skapende virksomhet er utforskende prosesser der barns og voksnes taktile og haptiske erfaringer er sentrale i interaksjon med ulike materialer og teknologier. De siste årene har det vært en gjennomgripende digitalisering av materialitet i samfunnet. Denne digitaliseringen innebærer at læringsmiljøer i stor grad flyttes fra det fysiske til virtuelle og fra fysiske materialer til virtuelle objekter og berøringsteknologi. Dette skjer både i barnehagen og i barnehagelærerutdanningen. De siste årene har det vært en fornyet interesse for sammenhengen mellom kroppslige interaksjoner og kognisjon i studier som dokumenterer læring som kroppslig forankret. Imidlertid er det gjennomført få empiriske studier av *embodied kognisjon*[2] for å undersøke sensoriske og utforskende aspekter ved interaksjon med digitale teknologiers materialiteter. Det overordnede forskningsspørsmålet i denne doktorgradsavhandlingen er: *Hvordan kan utforskende taktile og haptiske interaksjoner med fysiske og virtuelle materialiteter legge til rette for sense-makings*[3] *prosesser?* Det teoretiske rammeverket for denne avhandlingen er knyttet til embodied kognisjon-teori. I følge denne teorien utvikler vi kunnskap (make sense) gjennom sensoriske erfaringer forankret i kroppen. Den metodologiske forankringen i denne studien er arts-based research (ABR), og jeg tar i bruk ulike ABR metoder for å undersøke haptiske og taktile erfaringer. Studien henter inspirasjon fra sensorisk etnografi og a/r/tografi og støttes av videodokumentasjon.

I tre casestudier undersøkte jeg sense-making i taktil og haptisk interaksjon med fysiske og virtuelle materialiteter ved hjelp av fire delspørsmål: *Hva skjer når vi*[4] *åpner for eksperimentelle og uforutsette prosesser som transformerer fysiske og digitale materialer og fenomener i skapende handlinger? Hvordan legger en bildebokapplikasjon til rette eller begrenser sense-making gjennom taktil og haptisk interaksjon? Hvordan utvikler barn*

[2] Jeg oversetter embodied cognition til embodied kognisjon. Jeg velger å bruke denne betegnelsen fordi embodied ikke kan oversettes direkte til kroppslig.

[3] Sense-making kan ikke oversettes direkte til norsk. Begrepet er sentralt innenfor retningen *enactivism* - embodied kognisjon-teori (Di Paolo & Thompson, 2017). Begrepet understreker hvordan kognisjon er tett forbundet med kroppen og sansene.

[4] Forfatterne: Ann-Hege Lorvik Waterhouse, Lovise Søyland og Kari Carlsen.

forståelse (make sense) om verden gjennom utforskende taktile of haptiske interaksjoner med fysiske og virtuelle materialiteter? Hvordan utvikler jeg forståelse (make sense) om en gruppe barns og mine egne bevegelser i fysiske og virtuelle omgivelser gjennom a/r/tografiske utforskinger?

Den første casen var forankret i en formingsfaglig undervisningskontekst i barnehagelærerutdanninga ved Universitetet i Sørøst-Norge. Studentene ble invitert inn til å utforske og eksperimentere med forskjellige materialer og teknologier i et prosjektrom. Målet var å undersøke hva som skjer når det åpnes for eksperimentelle prosesser med ulike materialiteter i utforskende og skapende prosesser. Den andre casen var en utforskende undersøkelse av mine egne taktile og haptiske interaksjoner med en bildebokapplikasjon. Applikasjonen ble valgt på grunn av sin innovative bruk av VR (virtual reality) og invitasjon til utforskende interaksjon gjennom berøring og bevegelse. Den tredje casen undersøkte barns sense-making og utforsking av fysiske og virtuelle materialiteter i skapende prosesser. Barna ble invitert inn til å utforske og samhandle med ulike materialer og teknologier i et tilrettelagt prosjektrom. Målet var å avdekke hvordan barns sense-making utspiller seg gjennom utforskende taktile og haptiske interaksjoner med fysiske og virtuelle materialiteter.

Gjennom studien avdekkes seks hovedtemaer som har teoretiske og praktiske implikasjoner for utdanning. Disse temaene er: (1) Taktile og haptiske dimensjoner av materialitet er brobyggere mellom materialer og det virtuelle, (2) Følelser og forestillingsevne er kroppsliggjorte kapasiteter i sense-making i interaksjonen med virtuelle materialiteter, (3) Virtuell materialitet kan initiere nye oppdagelser og forme erfaringen av den materielle verden, (4) Digitale teknologier og strategier som gir muligheter for medskaping og utforskning er avgjørende for sense-making, (5) Kollektive utforskninger påvirker sense-makings-prosessen i interaksjon med digitale teknologier i fysiske omgivelser, (6) Haptisk visualitet og kunstnerisk utforsking kan utvide innsikten i sense-making og taktil og haptisk interaksjon.

Søkeord: Sense-making, taktil og haptisk interaksjon, virtuell materialitet, haptisk visualitet, forming og skapende virksomhet, barnehage, embodied kognisjon.

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Lovise Søyland, Kongsberg, Norway, January 2021

List of Original Publications

This dissertation is based on the following original publications that are referred to in the text by the Roman numerals I–IV. The original publications are reprinted in this summary with permission from the journals and the copyright holders.

I) Waterhouse, A.-H. L., Søyland, L., & Carlsen, K. (2019). Eksperimentelle utforskinger av materialer og materialitet i transmaterielle landskaper [Experimental explorations of materials and materiality in transmaterial landscapes]. *FormAkademisk*, *12*(1), 1–21. https://doi.org/10.7577/formakademisk.2648

II) Søyland, L., & Gulliksen, M. (2019). Sense-making through touch interaction with a picturebook app. *Nordic Journal of Childlit Aesthetics, 10*(1), 1–12. https://doi.org/10.18261/issn.2000-7493-2019-01-02

III) Søyland, L. (2020). Children's sense-making through exploration: Grasping physical and virtual materialities. *FormAkademisk, 13*(3), 1–21. https://doi.org/10.7577/formakademisk.3534

IV) Søyland, L. (in press). Making sense of movement: A/r/tographic explorations of physical and virtual environments. In N. Lee, J. Ursino, M. Mosavarzadeh, & R. Irwin (Eds.), *Walking matters: Material and digital a/r/tographic explorations.* Springer.

Personal Contributions

Publication I: For this article, I was the second author. This article is based on an arts and crafts educational project in Norwegian early childhood teacher education (ECTE) at the University of South-Eastern Norway (USN). The article was a collaboration among Ann-Hege Lorvik Waterhouse, Kari Carlsen, and me. We three authors contributed equally to data generation and writing the article.

Publication II: For this article, I was the first author. I had the idea and initiated writing the article. I conducted the data generation, which involved interaction with and following the story line in the app Wuwu & Co. Marte S. Gulliksen also worked on the story line. I completed the analysis, and the tentative main findings were narrowed down and explored through discussions with Gulliksen. We contributed equally to writing the article.

Publications III and IV: I was the sole author of these two articles, which are based on my own data generation.

Foreword

Writing and finishing this dissertation has been a special experience. It has been surreal to focus on physical touch as a fundamental part of our cognition and learning, at the same time as COVID-19 has demanded that we humans must keep physical distance, and in that way, affected humans' lives and education systems worldwide. The pandemic has limited physical human contact and physical style learning for millions of children and university students. Thus, it has been timely to examine learning with digital technologies while our society and education have been digitized at an even more rapid speed than ever, and the digitalization of materiality has increased enormously. It has also been thought-provoking to focus on arts and crafts education at a time when the arts may have become even more important as the means to initiate our sensitive and emotional experiences, to "touch us," to force us to reflect, and to give us hope for a better future.

Photo by: Lovise Søyland

Table of Contents

1 Introduction

1.1 Touch, Embodied Sense-Making, and Materiality

Over millions of years, our hands have shaped our minds, and our sensing, moving, and touching body may have played a far more important role in human development than we had originally imagined (Lerner, 2017, pp. 48–49). Our senses are deeply ingrained in the materiality of the world (Schilhab et al., 2018, p. 2), and our embodied minds are shaped by touch interactions with the environment (Shapiro, 2017). In this dissertation, I call attention to one of the most central bodily factors in human development: our sense of touch. It is important to focus on embodied sense-making as we face a global move toward digitalization of materiality (Browaeys, 2019). We humans adapt to continually changing circumstances, and digitalization requires changes in how we use our embodied minds. How this new materiality makes sense to us, how we can grasp it, and how it shapes our minds might be at the very beginning of understanding.

What we know is that we need to grasp physically to be able to grasp cognitively (Fredriksen, 2011a, p. 93). This is because our cognition is grounded in our bodily interactions with the environment, and it is tied to our bodies' sensory experience (Fugate et al., 2018, p. 1). Through embodied interaction with the world, we – humans – learn to make sense of it and get to know our surroundings, each other, and ourselves. Our cognition is directly linked to our ability to act, afforded by the environment (Gibson, 1979, p. 127). Acknowledgement of the connection between embodied action and cognition has gained traction in recent years in studies documenting learning as an embodied process (Bengtsson, 2013; Gulliksen, 2017; Kiefer & Trumpp, 2012).

Throughout our lives, we are in constant touch with our surroundings (Jewitt & Leder Mackley, 2019, p. 91). Just before the eighth week of gestation, an embryo develops sensitivity to tactile stimulation (Nicholas, 2010, p. 6), and touch is one of the first senses through which we experience the world around us. The concept of touch covers a wide field of touch experiences; we can both touch and be touched as we move about in our surroundings. Researchers in the psychology field, such as Field (2001) and Nicholas (2010), and from sociology such as Paterson (2007), highlight how our tactile and haptic perceptions are crucial to our experience, development, and sense-making. However, touch gets little attention in our

society (Jewitt & Leder Mackley, 2019, p. 92). An example of this is how today's young children are called the "touch generation" because of their extensive use of touch devices (Nicholas, 2010, p. 6). This is a paradox because touch screens can distance children from tactile perception and lead them to experiences that are largely audio-visual. This paradox and how this affects children has received little attention; touch is still one of the least studied senses and is ignored in many fields (Prescott & Dürr, 2016, p. 1). This may indicate why it is underestimated in current educational theory and research.

Arts and crafts education is fundamentally explorative and creative in nature (Gulliksen, 2017). The concept of arts and crafts education reflects the close connection between perception and action. We use our senses, hands, and body to manipulate, explore, and shape materials in making processes (Groth, 2017). This happens in close connections between body and mind, and between making and sharing meaning. However, the sense of touch has been neglected in many fields (Jewitt & Leder Mackley, 2019, p. 92), while visual and auditory cognition has been given extensive attention in education (Nicholas, 2010, p. 1). This is a tendency that largely emphasizes knowledge and perception based on vision, and it can be seen as a symptom of dualistic thinking (Springgay, 2005, p. 34). This dualism between the senses is problematic given that touch is woven into our wider sensory perception (Paterson, 2009, p. 129). René Descartes was one of the most famous philosophers who initiated the mind–body dualism concept (Johnson, 2007, p. 3). From an educational perspective, it is also problematic that dualistic theories, which separate the mind from the body in the creation of knowledge, have been dominant in Western Europe for such a long time.

One of Norway's oldest programs for arts and crafts teacher education is conducted at the University of South-Eastern Norway (USN). I have been working within arts and crafts early childhood teacher education (ECTE) and teacher elementary education at USN for the last ten years. During these years, I have experienced how my students make sense of their world during their crafting processes. In my profession, I have become more aware of the value of my position by focusing on handling and sensing in my teaching and research. I emphasize a practice that involves bodied, haptic and sensational experiences through exploration and creative activity where materials have a central role (see Carlsen, 2015; Fredriksen, 2011a). This study is positioned within an epistemological perspective which acknowledges that our minds are embodied (Shapiro, 2017), and within an arts-based research (ABR) methodology. According to Barone and Eisner (2012), haptic and tactile experiences are a central platform for examination. To develop an understanding of sense-making and sensory experiences, I relate to ideas from sensory ethnography (Pink, 2015) and a/r/tography (Irwin et al., 2019),

which I understand to be part of the ABR methodology. A/r/tography describes a person's merging of the different identities as "an" artist, "r" researcher, and "t" teacher in teaching and research (Springgay et al., 2008). These identities are incorporated in me and are thus some of the prominent identities with which I make sense of the world and the identities that this project has passed through. These identities are present throughout my study, interwoven with each other and part of my sensorial approach to understanding my own and others' sensory experiences (see Figure 1).

Figure 1. A collage of me in interaction with a group of children. The photos used in the collage were taken by the children involved in this study. The photo collage was made by me.

1.1.1 Key Concepts of the Study

In this dissertation, I understand *matter* as all we can touch and which has a body and shape (see Browaeys, 2019, p. 3). I understand this to be the stuff which bodies are made of, and that matter has features such as size and mass. In an arts and crafts context, matter can be understood as what we make something of, while materials are what we make something with. At the same time, our surroundings can be described as material. Materials and manual technologies have a key role in arts and crafts education and offer a world of exploration (Carlsen, 2015; Fredriksen, 2011a; Gulliksen, 2017). In early childhood education (ECE), children craft with diverse materials, explore them, and interact with them in diverse ways, often with their whole bodies. By using their bodies and hands, they can make imprints by manipulating and transforming their surroundings, for example, by shaping clay with fingers. While in use, technologies are in a close relationship with hands and bodies. Throughout time, humans have developed and adopted various technologies, such as tools, machines, and other technological products, into our society. In today's arts and crafts education, both traditional tools such as handheld knives and paintbrushes are used, in addition to digital technologies like touch devices, various software programs, and projectors.

Materiality refers to our perception, our experience of our surroundings (Ingold, 2007), which means that materiality is our experience of the texture of an object. Pink et al. (2016, p. 13) acknowledge that "materiality is a process, a flow and connections." Materiality also refers to the representation in our brain maps (Groh, 2014, p. 69f) of, for example, an object; this will be explained more thoroughly in the theory chapter. The verb *grasp* reflects both how our surroundings can be touched – how we make sense of them through sensory perception – and how grasping through our embodied minds is central in developing understanding. Since the perception of materialities depends directly on the senses, new theories of the knowing body in sense-making (Shapiro, 2017; Thompson & Stapleton, 2008) can contribute to deepening understanding in this area.

Materiality is closely connected to matter and materials (Browaeys, 2019, p. 4). The *digitalization of materiality* (Browaeys, 2019) in educational settings involves a change from using concrete materials into the virtual realm. This development prompts examination because this change might create distance between the child and the materiality. Browaeys (2019, p. 5) discusses how this new materiality alludes to "phenomena in the realm of the intangible" and that we need to consider it as the "emergence of a matter which is 'other.'" Virtual materiality can be understood to be in "the grip of invisible matter" (p. 5). New *knowledge on how the body is shaping the mind* through embodied interactions with the environment (Fugate et. al., 2018, Shapiro, 2017) is important as we turn toward this digitalization of materiality. Embodied cognition theory is important because it explains how the "cognitive processes are deeply rooted in the body's interactions with the world" and its sensory perception (Wilson, 2002, p. 1). This theory might therefore contribute to explain how the environmental change – the digitalization – will affect our cognition and experience. In addition, it is important to study if and how the digital and virtual dimensions can add new aspects of materiality and open up new possibilities to explore. Embodiment and explorative touch interactions with the environment play a central role, especially in children's sense-making processes, and are central components in arts and crafts education (Fredriksen, 2011a). This is the reason why I think it is important to study these aspects from the arts and crafts education perspective. I particularly believe that it is important to study touch and exploration in the context of materiality and digitalization of materiality. Before I go deeper into describing the research context and problem, I will explain the central concepts of this study.

Sense-making in this study is described as a person's active process of transforming the world into an environment that has meaning, significance and value for them (Thompson & Stapleton, 2008, p. 25). The term sense-making is a central concept in the enactive approach in

cognitive science described by Thompson and Stapleton (2008). I use the term instead of words like thinking, meaning making, or learning. This is to emphasize how I have positioned the study theoretically and to emphasize that learning is embodied and happens through our sensory experiences. I build on an understanding that sense-making occurs in various degrees, from the orientation of individual sense-making to joint sense-making (Di Paolo & Thompson, 2017, p. 75). In this way, joint–collective interaction in an environment is also central in this study.

We experience our environment through our *bodily senses of touch*, sight, hearing, smell, and taste. Touch covers a wide range of different touch perceptions. The sense of touch in this dissertation is defined as *tactile* and *haptic* perception. Tactile perception is understood as physical contact through our skin. Haptic perception involves our position, state, and movement of the body in space, such as when we grasp a person's hand or when we walk into a room (Paterson, 2007, p. ix). The terms are used differently within the various disciplines.

I use the term *interaction* in this dissertation. When I started working on this study, I considered using the term intra-action, a perspective that points to new materialism where materials to a greater extent are considered to have agency (Barad, 2008). Early in my study, the term interaction was found to be more useful in the context of my research. Embodied cognition theory describes sense-making on an individual and social–cultural layer and resonates well with the term interaction in developing an understanding of sensory experiences on both an individual and collective level. This way of positioning my project can be criticized as anthropocentric, but in this context, it is more a position or perspective that is useful in developing a specific understanding. The intra-active perspective refers to the phenomenon that arises when the human and non-human (materials, digital technologies, etc.) intra-act. In the context of my study, this becomes too vague to describe embodied knowledge in interaction with, for example, virtual materiality.

Exploration is seen as a strategy to make new discoveries; it requires action and is closely connected to creativity, making, and play (Eisner, 1990, p. 43–44; Fredriksen, 2011a, p. 299; Springgay, 2005, p. 35). Creative activity can be an entrance into exploration, and exploration is a central part of educational arts and crafts. An explorative process is open-ended, similar to a rhizomatic process. The term *rhizome* is derived from botany and was developed as a philosophical concept by Deleuze and Guattari (1987). It can be helpful to describe how sense-making is nonlinear and shoots off in different directions like a rhizome. This dissertation focuses on explorative processes, which means that it is the processes and not necessarily the outcome of the process that is the focus. Tactile and haptic perception is thus a part of a process of exploration. In this dissertation, I have chosen to use the term *exploration* and not the term

experiment, which my co-authors and I used in the first publication. The reason why I use the explorative term is that it is more closely connected to arts and crafts education and more open-ended, while the experimental term can be confused with and evoke associations with scientific experiments.

Materials and digital technologies have both similarities and differences. Our surroundings are material; through our sensory perception and embodied minds in interaction, we can experience the world's materialities (Ingold, 2007). *Digital technologies* are seen as *tangible objects made of materials, while also being a medium and a tool*. Materials and digital technologies are seen as substances in the world (material), and digital technologies, a means of creating substance in the world (digital). Most materials are tangible, while some materials as light can be experienced as both intangible and tangible, meaning, for example, that heat from light on skin can be felt from light. In the first publication, my co-authors and I used the words *digital materials*; however, during my work on this dissertation, I found this term to be vague in the context of my study.

The main purpose of this study is to discuss interaction and exploration that involve digital technologies. This can be seen as a way of making sense through and with digital technologies. I have mainly studied types of digital technologies that are currently available in Norwegian ECE and ECTE, such as touch devices and projectors, but I have also included mobile phones in this project. A digital touch device in this study is seen as a piece of physical hardware that functions as an interface between the user and the software. A touch device can digitally produce virtual materiality, including images, sounds, and interactive features, in a virtual 3D space. A projector can, in addition, mediate a virtual materiality. The term *hardware* is understood to be all physical objects in relation to digital technologies.

The terms *physical* and *virtual materiality* are used to emphasize the differences in how materialities can be grasped. When I started working on this dissertation, I used the term digital materiality to describe the materiality that, for example, appears on a touch device screen by means of a software program. However, during the work, I found the description of the term digital materiality vague in the context of my study. Early in this project, I described the experience of digital materiality as an amalgamation of the visual, the auditory, and the physical material of the touch device. This is a vague definition because all sensory experiences are multimodal, and it does not explain how the experience of digital materiality is different from the physical materiality. The term *digital* refers to electronic equipment in general, which is using information in the form of numeric code/digits (Cambridge Dictionary, n.d.), while the term *virtual* refers to something that is *not physically existing as such but made by software to*

appear to do so (Oxford English Dictionary, n.d.). In this way, the concepts in relation to materiality changed from digital to virtual.

Virtual materiality is mediated through a digital technology (Søndergaard, 2013; Søyland & Gulliksen, 2019). It can be experienced through vision and hearing, but not touched, smelled, or tasted. When a person interacts with a touch device, the materials that the touch device is made of can be touched, but not the virtual materiality. In the first publication, my co-writer and I used the term *transmateriality* to describe the expressions that occur when a person experiences physical and virtual materialities simultaneously. This is an interesting term in the context of digitalization of materiality; however, I found it more useful to single out the different materialities and use the terms physical and virtual materiality in the context of this study.

I use the terms physical and virtual materiality to describe the difference in how they can be experienced. In this study, virtual materiality is understood to be an illusion, which means a visual representation of physical objects and materials. Virtual materiality is made available through the software of a digital technology and can be understood to be a digitally mediated material. In addition, the comprehension of something through a visual representation depends on a person's past experience of its material counterpart, such as shape and tactile texture, and related memories and emotions connected to the experience. In other words, this might mean that there is a poorer response and less sensory information when experiencing virtual rather than physical materiality. The terms physical and virtual materiality are also necessary to explore what happens when they *occur simultaneously in different combinations* and when they arise at the moment and add something together to the experience. For example, through experiencing a virtual materiality projected on an object, it is possible to experience both physical and virtual materiality simultaneously. This indicates that there might be new opportunities to explore and make sense of the world.

1.1.2 The Study Started to Take Shape

When I started to plan my examination of *how explorative touch interactions with physical and virtual materialities can facilitate processes of sense-making,* I started out with two different approaches. The first was to study ECTE students' exploration in combining materials (such as natural materials and plastic) and digital technologies (such as mobile phones, iPads and projectors). The other one was to study my own interaction with a virtual reality picturebook app that has won awards for its innovative use of interactivity. In other words, one of the

approaches was to study the combination of materials and digital technologies, which is largely available in ECE. The other one was to study a touch device with software that has gained attention for its use of virtuality.

I chose to base the first study on an existing arts and crafts educational project, which has been developed through my work in ECTE. The project has been developed together with colleagues from the Department of Visual and Performing Arts Education at USN. In this study, I took an active explorative position. It was also important for me to study my own sense-making in interaction with the app. Through taking an active part in exploration with students and by studying my own sense-making, I could use the knowledge from these studies to tailor the study (Stake, 2010) involving children. The study involving children has similarities with the first study, and the children were invited into a facilitated environment. I explored together with them and observed these young children's touch interactions and explorations of materials – such as a dried red onion, a leek flower, and a buck skull – and technologies – such as iPads, projectors, and flashlights.

In the examinations of student teachers, children's and my own touch interactions, I needed a theory that would highlight how cognition is embodied. In this context, I think it important to remind you as a reader that I am not from the field of neuroscience but that I use theory from this field as a theoretical foundation to develop understanding. This theory will be explained in detail throughout the theory chapter. In the following, I will present the context of my study.

1.2 Educational Tendencies

First, in this section, I describe international educational tendencies, which have been important for choosing the topic of this study. They represent the foundation for understanding the aim of my project. Second, I briefly elaborate on the development of the Norwegian elementary school since Norwegian ECE and ECTE have developed in close connection with the political management of Norwegian elementary school. In addition, ECE is part of the Norwegian elementary education. At the end of this section, I will describe today's context of arts and crafts in ECE in Norway. I will especially look into earlier research on exploration, creativity and haptic practice, and tendencies in relation to this area in ECE policy documents.

As stated, I emphasize a haptic and exploratory practice and understand arts and crafts processes as fundamental in making sense of the world. Biesta (2018) argues in a paper presented at The 5th NAFOL (the Norwegian National Research School in Teacher Education)

conference that "real education always involves a risk, because education is not about filling a bucket but about lighting a fire." I understand his argument as being at the heart of what education is about. I understand his metaphor of "lighting a fire" in such a way that education should create emotional engagement and involvement in children. Biesta (2013, p. 2, 2018) criticizes education for being focused on the production of measurable learning outcomes in a few subjects. He also points to society's increasing need for controlling education. Policy makers, politicians, the popular press, "the public," and organizations such as the Organisation for Economic Co-operation and Development (OECD) and the World Bank "want education to be strong, secure, and predictable," and the symptom of this is that the risk is taken out of education (Biesta, 2013, p. 1). In a paper presented by Brunstad and Olivierio (2018), they outlined how the controllable way of education highlights learning as computerization of knowledge, an input–output logic, training children to get the right answers to questions, a mathematic logic in learning without the explorative. Brunstad (2015) argues for the importance of the unforeseen in education and learning. I understand the tendency that Biesta (2013, 2018) and Brunstad (2015) underline as a way *toward a devaluation of experiential knowledge*. My interpretation is that a goal-oriented instrumental approach to learning thus threatens to diminish explorative processes that are free from expectations. In addition, there are diminishing opportunities for children to explore through multisensory experiences which, from my point of view, are crucial in their development and the process of sense-making. Thus, my study focuses on explorative interaction with materiality that can take different directions and have unpredictable outcomes for each child. Thus, I am not interested in measuring children's learning, but in better understanding how the process of sense-making evolves.

I agree with the criticism that Biesta (2013) directs at OECD; at the same time, I acknowledge that the OECD project: 21st Century Skills (OECD, 2018) has implications for education that I see as positive. The aim of the OECD project is to help countries find answers to what knowledge, skills, attitudes, and values today's young children need to thrive and shape their world. One of the positive recommendations is the argumentation for a personalized learning environment that supports and motivates children to nurture their passions and make connections among different learning experiences (OECD, 2018, p. 4). These are central aspects of arts and crafts education. OECD also attributes a broad understanding of knowledge in relation to children's use of digital technologies. The report states that practice should involve creating, viewing, observing, writing, and designing. It underlines that children need "a broad set of knowledge, skills, attitudes and values in action" (p. 4). Creative thinking and curiosity

are emphasized as central in children's process of sense-making. It also emphasizes the social and emotional, physical and practical aspects of skills.

As I understand it, there are also positive tendencies for education within the newer learning science (Sawyer, 2014). A central aspect of this is that the learning science acknowledges learning as a process of change and an internal and external process of transformation, according to Sawyer. My interpretation of this is that this learning science values the process – the child's constant process of change in interaction with a social and cultural environment. This understanding corresponds within the epistemological perspective of my study. Sawyer (2014, p. 2) states that the learning sciences approach highlights the learners' active participation in creating knowledge and emphasizes that "educated graduates need a deep conceptual understanding of complex concepts and the ability to work with them creatively to generate new ideas, new theories, new products, and new knowledge."

The Norwegian elementary school and international educational tendencies have an impact on Norwegian ECE education. In the Norwegian elementary school, the subject is called "Arts and Crafts." In Norway, educational reform was introduced in 2006 in primary, lower secondary, and upper secondary education and training. In the years leading up to the introduction of the Norwegian Knowledge Promotion Reform 2006 (in Norwegian, *Kunnskapsløftet* 2006; Ministry of Education and Research [MER], 2006), the Norwegian school became more goal-oriented and moved toward a more behavioristic epistemology than earlier (Karseth & Ultstup Engelsen, 2007). This was part of a reorientation toward a school which emphasizes testable knowledge, and not necessarily children's process of exploration. The Norwegian policy document focused on five basic skills: oral, reading, writing, digital, and numeracy skills (MER, 2006), with an emphasis on knowledge that is possible to test. The value of children's sense-making process through arts and crafts education was not part of this test system. This development can be seen as a consequence of the focus on major international comparative studies such as PISA (Programme for International Student Assessment) (OECD, 2018). Norwegian educational policy documents were earlier criticized for representing a goal-oriented skill perspective and an *instrumental view on learning with digital technology* (Nordkvelle et al., 2015). From my experience and point of view, I would argue that arts and crafts education is a counterbalance to this thinking. I share this view with Brunstad (2015, p. 358), who stresses that *arts and crafts education has an important contribution in this regard.*

One positive development, as I see it, in recent years is the *new curriculum for primary and secondary* school introduced in 2020, which sets the focus on deep learning, joy of making, and explorative processes (MER, 2020). Another positive perspective in relation to arts and

crafts education and digital technologies is the *makerspace movement* that has grown in the field of education in recent years (Burke & Crocker, 2019; Clapp et al., 2016). The makerspace movement includes the emerging role of making in education. Recently, in the field of education, there has been significant interest in how STEAM (Science, Technology, Engineering, Arts and Math) can be utilized in education. Makerspace works are sites for creative production where children can make something together using digital and manual technologies and materials to explore ideas (Sheridan et al., 2014, p. 505). I understand this as a *democratization of technology* – technology made available for children in activities both inside and outside school and ECE. Makerspace pedagogy involves a collaborative mindset. Studies have shown that engaging in makerspace activities enhances children's creativity and imagination (Burke & Crocker, 2019). The context of my study is not within makerspaces; however, it is interesting and relevant to take account of this movement and way of thinking in relation to my study.

1.2.1 Norwegian ECE, ECTE, and Arts and Crafts Education

In Norway, ECE is for children under school age, and most children attend ECE from the age of one to six, even though it is not a mandatory part of the educational system. The Norwegian National Framework Plan for Kindergartens (MER, 2017, p. 22) states that children should experience a stimulating environment that supports their desire to play, explore, learn, and master their environment. Norwegian ECE is divided into six thematic knowledge areas, one of which is "Art, culture and creativity" (MER, 2017, p. 50). This learning area covers arts and crafts as well as genres such as visual art, music, dance, drama, language, literature, film, architecture, and design (MER, 2017, p. 50). In other words, the arts and crafts have a central place in Norwegian ECE; however, there are reasons for being concerned about this state of affairs. I will come back to this. First, I will explain the tradition of Norwegian ECE with a special focus on arts and crafts education.

Focus on embodiment and haptic perception in children's development and sense-making has always had a central place in Norwegian ECE (Carlsen, 2015). Gibson (1979) and Dewey's (1934/2005) theories have been central in explaining and understanding children's material interaction and exploration in Norwegian ECE. Arts and crafts education highlights the necessity of children's direct experience with materials in their process of sense-making (Carlsen, 2015; Fredriksen, 2011a). In this context, children are seen as competent and active individuals who learn through their embodied interactions and construct their own knowledge

within the contexts of arts and crafts education (Fredriksen, 2011a, 2011b). This perspective stems from a sociocultural perspective on learning (Vygotsky, 1978) and has been dominant in ECE for some time (Mangen et al., 2019, p. 242). In this practice, the interaction and relation between children and adults has been at the forefront. The sociocultural tradition has faced criticism because it is considered as downplaying the sensory, cognitive, and emotional aspects in children's processes of sense-making (Mangen et al., 2019, p. 242). My interpretation of this is that the embodied cognition perspective (Fugate et al., 2018) is useful to highlight children's individual haptic and emotional aspects of learning in interaction with their surroundings in addition to their social and collective processes of interactions. This perspective moves the focus from social interaction to interaction with materiality, while also including social interaction. In the context of children's interactions with their material surroundings, I would also mention the practice and philosophy of Reggio Emilia (see Vecchi & Giudici, 2004). The Norwegian ECE and ECTE are to some extent inspired by this practice (Carlsen, 2015). Moreover, as I see it, there are important correlations between arts and crafts education in ECE thinking and Reggio Emilia's philosophy and thinking.

Studies in the field of arts and crafts in ECE confirm the importance of children's explorative interactions of materials in their processes of sense-making (Carlsen, 2015; Fredriksen, 2011a; Waterhouse, 2013). Material exploration and play in ECE goes all the way back to Friederich Wilhelm August Fröbel (1782–1852) (Carlsen, 2015, p. 56) and is a central part of ECE's arts and crafts education (Carlsen, 2015; Fredriksen, 2011a). Play is seen as an activity without predetermined outcomes and as an explorative process through which they can discover new possibilities and create new experiences (Eisner, 1990, p. 44). Play is also closely connected to children's imagination (Eisner, 1990, p. 43). Children engage in explorative interactions, actively seeking sensory input to enrich and support interpretation, to search for problems and find solutions (Carlsen 2015; Fredriksen 2011a, p. 299). Arts and crafts processes and explorations are ways to get closer to the world and to understand more of the world, oneself, and others. Experience with arts and crafts processes can help individuals to explore "the familiar in unfamiliar ways and transform the ordinary into the extra-ordinary" (Eisner, 2002, p. 17). Other studies in ECE research emphasize that "children's multisensory exploration of material, tangible objects in their physical surroundings is fundamental to their cognitive development" (Mangen et al., 2019, p. 236). Creative processes are closely connected to exploration and a way to be attentive to the body and a way which we come to know, in, with and through the body (Springgay, 2005, p. 35).

During the summer of 2019, I was lucky enough to visit a group of young children and Sylvia Kind in her ECE studio at Capilano University in Vancouver, British Columbia. Kind (2010, p. 114) states that "failure, struggle, uncertainty, and not knowing the outcomes in advance may be difficult concepts for education to embrace yet they are essential elements of artistic practice." I joined Kind in material exploration together with a group of children aged two to six. This experience, as one among several of my tangential experiences as an a/r/tographer, underlines how explorative processes can provide many openings, potentials, and opportunities for children's sense-making. I did not have permission to take photos of children during my stay at Kind's studio. But in Figure 2, one of my photos from the studio can be seen, and a photo from Kind's website appears in Figure 3.

Figure 2. Children's studio at Capilano University. Photo by Lovise Søyland.

Figure 3. A photo of children exploring charcoal in the studio. Photo by Sylvia Kind. Retrieved from: http://encounterswithmaterials.com/charcoal-encounters/

Norwegian national guidelines for ECE recommend that teachers should use materials and tools in creative processes and explore these together with children in meaningful interaction (MER, 2017, pp. 22–23). The 2017 Framework Plan specifies that children should use their entire body and all their senses in their sense-making processes (MER, 2017, p. 22), and that children being explorative and creative in interaction with their material surrounding should be a focus. The plan calls attention to the value of the immediate and the process of making discoveries to expand their perspectives and gain new insights.

The notion that embodied interaction is essential to child development is not a new concept; however, there has been renewed interest in embodiment in ECE. Several studies have drawn attention to the importance of children's embodied exploration, emotions, and active engagement with the material worlds in sense-making and development (Carlsen, 2015; Fredriksen, 2011b; Pacini-Ketchabaw et al., 2017; Waterhouse et al., 2019). In my opinion,

there were positive changes in the 2017 Framework Plan regarding arts and crafts education. However, arts and crafts education has had a weaker position in Norwegian ECE in recent years than just 10 to 15 years back (Bamford, 2012; Carlsen, 2015; Waterhouse, 2013). Another worrying condition is that children's access to and use of two- and three-dimensional materials was impaired in Norwegian ECE just a few years ago (Carlsen, 2015). However, hopefully, the growing attention to embodiment in education (Bengtsson, 2013; Gulliksen, 2017; Kiefer & Trumpp, 2012) can contribute to redirecting the focus to the importance of children's arts and crafts education.

When I search for descriptions of children's digital competence in the 2017 Framework Plan (the current plan in 2021), I find many important guidelines which can facilitate good digital practices with children. The plan states that the staff shall "enable the children to explore, play and create using digital forms of expression" and "explore the creative and inventive use of digital tools together with the children" (MER, 2017, p. 45). I consider it to be a positive development that collective exploratory aspects of interaction with digital technology have been put on the agenda in policy documents. However, this will require additional knowledge and practice to facilitate the sense-making process with digital technologies in both ECTE and ECE. Thus, the aim of my study is to contribute to this field.

In this section, I have elaborated on "educational tendencies," political guidelines, and different ways of understanding children's learning and sense-making in arts and crafts education. The complexities involved in sense-making can be overlooked in policy documents aiming to control the outcomes of education. This tendency can be seen as a devaluation of the experiential knowledge focus on production of measurable learning outcomes and a behavioristic epistemology in education (see Biesta, 2013; Carlsen, 2015; Karseth & Ultstup Engelsen, 2007; Otterstad, 2016). However, several studies have documented the process of children's embodied sense-making and experiential knowledge within arts and crafts education (Carlsen, 2015; Fredriksen, 2011a; Gulliksen, 2017; Waterhouse, 2013). In addition, children's arts and crafts processes are now underlined in Norwegian educational policy documents. Hopefully, arts and crafts education will always remain an important part of the education of all people.

1.3 The Digitalization of Materiality – Research Context/Problem

We are facing a digitalization *of materiality*, and due to this inevitable development, there is a risk of changing fundamental prerequisites for material interaction and experiential knowledge in learning environments. This development might affect children's sensory perception because the conditions of our surroundings influence the ways we make sense of the world and ourselves. A shift from the material world to extensive use of screens also entails a shift in a child's spatio-temporal relation with materiality.

The material turn, developed during the last 15 years (Barad, 2007; Lenz Taguchi, 2010), can be understood as a philosophical counterweight to the growing tendencies toward digitalization of materiality. A number of publications have put materiality on the educational, cultural, and academic agenda (see, for example, Eriksen et al., 2013; Gregersen & Skiveren; 2016; Martinussen & Larsen, 2018: Schilhab et al., 2018). Since the late 1900s, there has also been a linguistic turn, and linguistics has received much attention in our society (Luff et al., 2009). "Language matters. Discourse matters. Culture matters. The only thing that does not seem to matter anymore is matter," according to Barad (2008, p. 120). Barad's famous statement describes how materiality itself matters. The material turn arose as a counterbalance to the linguistic and social constructionism turn, highlighting that we can make sense of materiality in different ways, not only through words and symbols (Gregersen & Skiveren, 2016, p. 13). The role of sensation and knowledge gained through sensory experience is crucial in experiencing materialities (Eriksen et al., 2013, p. 10). Materiality is a process; it is relationally and performatively conditioned (Damsholt & Simonsen, 2009, p. 17). To describe materiality as a process is part of the tendency in material studies to describe, for example, the properties of materials as "material flow" (Ingold, 2007, p. 14). It is not something defined but a process emerging through our senses, a process of materialization (Pink et al., 2016, pp. 11–13). Through this process, we are affected (Damsholt & Simonsen, 2009, p. 16). Researchers in ECE have also put the *meaning of materiality* on the agenda (Lenz Taguchi, 2010). Nordtømme's study (2016) stresses how children's sense-making is situated and emerges through interaction with the materialities and conditions of their surroundings. Moxnes (2019, p. VI) states in her analysis that "materiality and the outside world play active parts in forming the here and now in education." I now turn to sensorial and explorative aspects in interaction with digital technologies.

1.3.1 The Sensorial and Explorative in Interaction with Digital Technologies

The social science approach has been the dominant scientific approach to examining digital technologies since the 1940s and 1950s (Erstad, 1993). In general, the field has been dominated by linguistics and literary studies, and characterized by quantitative research and by reception studies such as effect analyses (Illeris, 2002). It is possible that these traditions still contribute to characterizing the educational field of research with digital technologies. The dominant view among Western policy makers is to favor quantitative and large-scale trials (Kucirkova et al., 2019, p. 3), and the trend is going in the direction of substantiating a "disciplinary-oriented, one-dimensional understanding of children's technology use." Johansen (2015, p. 32) points out that there is a need to develop or see opportunities to use methods that can examine children's interaction with digital technologies in age groups who largely express themselves in ways other than verbally.

During the twenty-first century, there has been a rapid growth of and huge investment in digital technologies in children's learning environments (Kucirkova et al., 2019, p. 3). Particularly in the Nordic countries, educational institutions have embraced the new digital era and implemented *handheld touch technologies* on a large scale and at a rapid speed (Bølgan, 2018; Chaudron, 2015). An explanation of this in relation to ECE is that touch-screen technologies are considered to be especially appropriate for young children because of the devices' mobility and ability to be manipulated by smaller hands (Mangen, 2016, p. 470). A few years ago, Norway was racing to be the top European country with the largest number of children who had access to handheld touch technologies (Letnes et al., 2016, p. 6).

In general, few studies have examined young children's use of digital technology (Bølgan, 2018, p. 15; Johansen, 2015, p. 32). There is also a lack of qualitative research in this area (Bølgan, 2018, p. 15; Chaudron, 2015, p. 11). In addition, there are few empirical studies on the significance that digital technology has for children's learning when it is used wisely (Bølgan, 2018, p. 15; see also Johansen, 2015, p. 32). To use this wisely is a question of definition; it is not entirely clear what Bølgan (2018) means when she writes this, but she emphasizes the exploratory and creative aspects of the digital practice in ECE as being central. Studies reveal that the focus on digital technology in Norwegian ECE is largely focused on how digital tools from a learning perspective can promote early literacy and mathematical understanding (Jæger & Sandvik, 2019, p. 13). Another aspect in the discourse of the digital is that we are on the verge of risking a reductionist understanding of digital competence (Erstad, 2010; Letnes, 2014, p. 8). My interpretation of this is that digital competence can be limited to

something predefined and measurable within the scope of subjects. The increasing digitalization in ECE is an ongoing discussion characterized by polarizing opinions such as "for or against technology" (Mangen, 2016, p. 471) or "celebration" or "concern" (Drotner, 2009) about children's use of digital technologies. The discussion for or against technology exists both among teachers and the public (Jæger & Sandvik, 2019, p. 13). My impression is that teachers and scholars who are positive about the extensive use of digital technology in education often argue that digital technology itself is motivating children. In addition, education in general should keep up with the technological development in society. My impression is also that investments in digital technologies in education, in many cases, come from personal initiatives that are not necessarily based in research. On the other hand, teachers and scholars who are negative about digitalization argue that the benefits of using touch devices in learning are overblown and that the risks for stunting development can be high. The most critical are warning about drastic consequences such as digital dementia (Spitzer, 2014) and that swiping your fingers across a touch screen is one of the "dumbest things you can do with the hand" (Spitzer, 2013, p. 96).

When digital technology is used in ECE, it is important that it is not in consumptive use but *included in a creative and explorative process (*Bølgan, 2018). There are several studies that acknowledge that touch devices have the potential to be part of creative and explorative processes due to the combination of the devices touch screen, mobility, and audiovisual affordances (see Petersen, 2015; Waterhouse et al., 2019). Several researchers in the field of education and digital technologies emphasize the need to focus on children's explorative use of digital technologies (Bølgan, 2018; Erstad, 2010; Waterhouse, 2013). Letnes (2014) finds in her study that arts and crafts are a key entrance to the use of technology in educational practice. Blume (2015) underscores the potential for children's new experiences using digital technologies through artistic exploration. There are also several studies that highlight *the importance of the presence of the teacher* in ECE in explorative use with digital technologies together with children (Jernes, 2013; Letnes, 2014; Vangsnes, 2014). Jernes's (2013) study outlines that much of the explorative digital activities children do in ECE are without adult participation. She acknowledges that both children and adults should join in such activities. The origin of the instrumental approach to learning with digital technologies (Nordkvelle et al., 2015) and the tendency to focus on quantitative studies, such as effect studies in ECE (Kucirkova et al., 2019, p. 3), can be a consequence of the instrumental and logical structure that digital technologies are built on. From my experience as a teacher, I find educational digital technologies to largely contain software that has pre-programmed learning goals. Software,

such as open-ended apps, which does not have predetermined solutions and that invites children to create and explore is preferable (Bølgan, 2018, p. 99).

Over the last ten years, there has been a rapid development of digital technology that inherently changes the way we *physically and sensorially interact* with technologies in embodied forms of interaction and experience (Farr et al., 2012, p. 2; Jewitt & Leder Mackley, 2019). An example of this is how a touch device is tangible and mobile and provides more opportunities for a broader range of perception-based interactions, such as haptic and tactile touch, than traditional digital technology such as computers (Davidsen & Christiansen, 2014; Farr et al., 2012, p. 2). Even though technology has been developed in this way, studies of the role of touch and somatosensory perception for sense-making in interaction with digital technologies have received less attention than studies of audio-visual perception (Mangen, 2016; Nicholas, 2010, p. 1). However, there are some studies that are essential to note in the context of materiality, sensory experience, and exploratory perspectives. Merchant (2015) has studied young children's interactions and material affordances on touch devices, and he states that empirical studies that focus on materiality are important. He argues that "materiality is indicative of both the embodied and embedded nature of human experience, the multiple entanglements of humans with materials [sic] objects and artefacts, and the various supports these provide to human pursuits" (Merchant, 2015, p. 10). This underlines the importance of sensorial perception and the meaning of materiality in children's digital learning contexts. In Søndergaard's (2013) study of how children conceptualize virtual materiality in computer games, she emphasizes how the physical and virtual as phenomena are enacted differently, depending on the situation. Stenslie (2010) has explored touch in artistic, multimodal, and computer-based environments and finds that haptics bridge the gap between the physical and the virtual. He describes this as the material paradox of virtual realities (p. 128). This also implies that there is potential to use digital technologies in explorative embodied sense-making processes to a greater extent.

There are some important studies that address embodied and sensorial aspects of interaction with touch devices in education. Mangen et al. (2015) identify how bodily movements, such as the shift from forming letters with hand by pen and typing letters on keyboards, can affect a person's perception. Studies have confirmed how the way in which we manipulate objects on a screen (by swiping or tapping) differs from manipulation of paper pages (physical materiality) and reveals how these differences affect comprehension (Mangen & Schilhab, 2012). In addition, studies conclude that reading on paper and a screen affects the sensory experience, memory, and cognition, and that people retain less information reading on

a screen (Mangen, 2016). Schilhab et al. (2018, pp. 1–8) state how the "shift from print to screen has physical effects on how we engage the body while reading." Schilhab et al. (2018, p. 8) point to two distinct dimensions of the embodiment, the "spatio-temporal and the imaginary," and how "reading depends on direct experiences in the moment as well as in the past."

As described in section 1.1.2, one of the approaches in this dissertation was to study my own touch interaction with a virtual reality picturebook app. Software developers of picturebook apps have especially taken advantage of innovative use of digital technologies, such as virtual reality, to invite children to engage in multisensory experiences. Picturebook apps provide "multimedia stories that make use of the affordances of touch-screen technologies – most importantly, interactivity and a combination of modalities and media" (Mangen, 2016, p. 470). Mangen and Kuiken (2014) find that the fingers and hands have a central role in a person's experience of being immersed in a fictional world. Picturebook apps have been studied in relation to the theory of affordances (Schwebs, 2014) and multimodality (Al-Yaqout & Nikolajeva, 2015), interactivity and immersion (Nagel, 2017), intermediality (Henkel, 2015), and reading on a touch screen as multisensory and embodied experience (Mangen et al., 2019).

Central to the debate about sensorial and digital technologies is the *digital–material dichotomy* (Pink et al., 2016, p. 6). In their book *Digital Materialities: Design and Anthropology*, the authors describe how academic scholarship has developed the digital and material as two different concepts and that this is problematic. They stress how the digital–material connection is inseparable (p. 7). I think this emphasizes how important it is to develop and study a practice in ECE that includes the material and digital as intermeshed elements of processes and activities. The authors also state that it is problematic that the physicality of matter versus the intangible of a digital materiality is generally overlooked in practice-based disciplines of architecture and design (p. 7). This might also be something that is important to be aware of and that the digital–material dichotomy is something we should perhaps strive to break down.

The research field I have presented here emphasizes how the digitalization of materiality in children's learning environments is an issue under debate, both internationally and in the Norwegian educational context, and that it clearly will require further investigation. This debate was the background and my main motivation when I began to work on this study. I had an understanding that digitalization brings new challenges but also that there were untapped or undetected opportunities to use digital technologies to explore and make sense of the world for children. Newer theories on embodied cognition (Fugate et al., 2018) emphasize how important sensory experience, and especially haptic perception, are for children's development and sense-

making. These theories were also an important foundation for me when I decided to study sensory experience and especially explorative touch interactions in relation to materiality in ECE. My decision was based on my experience with children's exploration of materials and on educational theory and research that have confirmed how important this aspect is in children's sense-making. I was also curious about how the combination of different materialities could provide meaningful experiences through exploration and play and whether this could contribute to shaping children's understandings of the world (Figure 4). Another motivation for doing this examination was the lack of studies that involved adults' engagement and exploration together with children in digital contexts. The educational context, the digitalization of materiality, and new knowledge of the body in sense-making also indicate a need to develop methods to study sensory experiences in explorative interactions.

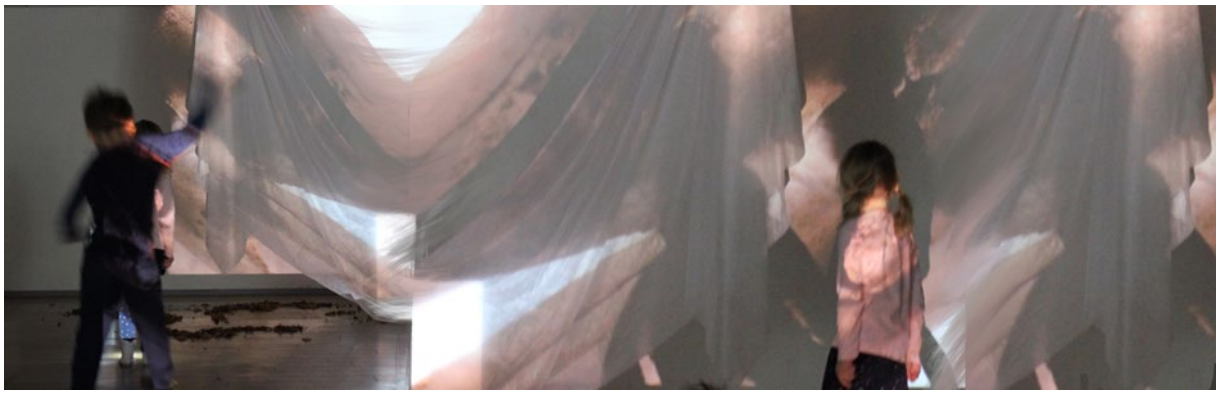


Figure 4. A collage of two children's explorations of different materialities in an environment. Photo by Lovise Søyland.

1.4 Aims and Objectives

In this project, I aim to contribute to the above noted discussion by developing an understanding of how explorative touch interactions with physical and virtual materialities can facilitate processes of sense-making. In the study, I have a special focus on haptic and tactile sensory experience. The purpose and intentions of the research are to develop new teaching and learning strategies and insights into potential ways to explore different materialities. My study aims to contribute to theoretical understanding and practice and to embodied methods that can help gain a deeper understanding of bodily and sensory experience in such contexts. This dissertation thus focuses on embodied sense-making in the research context of the digitalization of materiality and is informed by embodied cognition theory (see Figure 5 for contextual framing of the research).

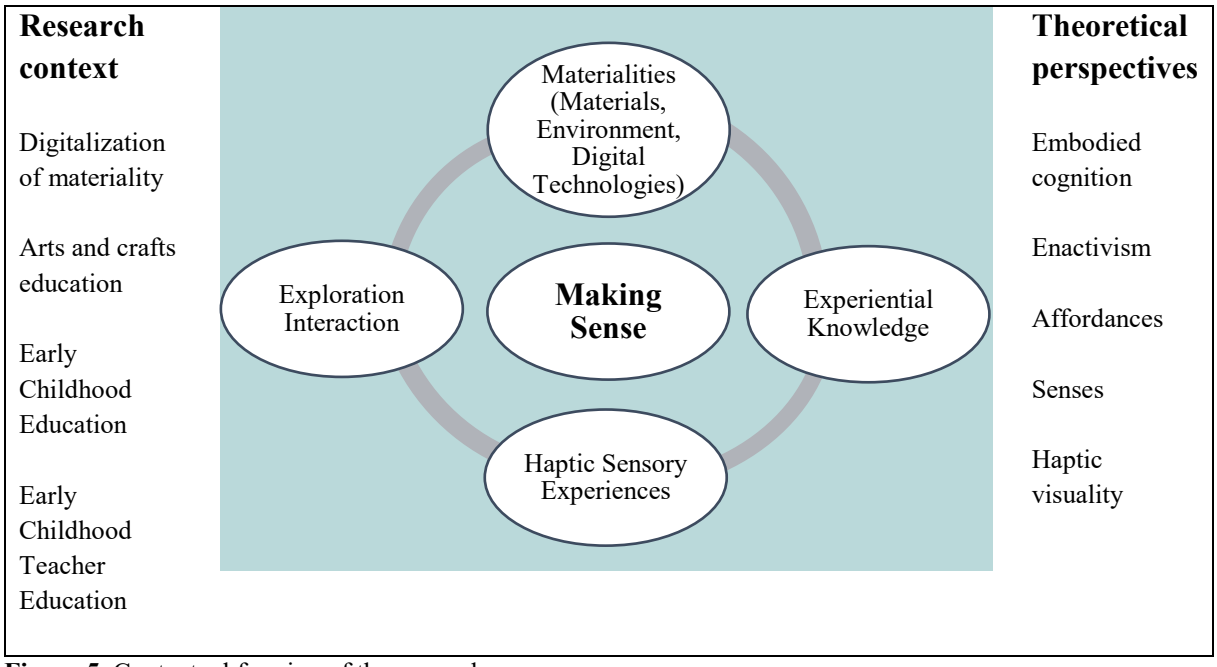


Figure 5. Contextual framing of the research.

In the following, I will describe the different aims and objectives in the three cases. I started this study by examining a group of students' explorations of different materials and materialities. Case 1 involved a three-day teaching project with students in ECTE at the USN. In addition to me, two co-researchers positioned as a/r/tographers were involved in the study: PhD student Ann-Hege Lorvik Waterhouse and Associate Professor Kari Carlsen at USN. The study was based on an arts and crafts teaching concept initiated by the three a/r/tographers involved. The study was conducted as practice-based research within ABR (Barone & Eisner,

2012). The empirical material was developed through preparation for teaching, our own observations and photography through collective explorations, and students' verbal utterances, processes, expressions, photos, and videos. The first aim was to facilitate a large-scale project room inviting students into explorative and experimental ways of engaging with touch devices, macro lenses, flashlights, projectors, and natural materials such as a buck deer's skull and dried leaves in the creative process. The second aim was to document and capture what happens in collective explorations with students when we a/r/tographers opened up to experimental, rhizomatic, and unforeseen processes combining different materials and digital technologies in creative processes. The third aim was to contribute to and be part of developing a renewed digital practice related to ECTE and ECE that involved exploration and engagement with materials and digital technologies in the creative process.

In Case 2, I studied my own touch interaction and sense-making process with a virtual reality picturebook app. The app was selected because of its innovative use of virtual reality and utilization of features, which indicated a potential to be explorative through touch interaction. To get closer to the phenomenon being studied, I examined it through an in-depth explorative inquiry, from an insider perspective, supported by diary questions (Groth, 2017) and audio-visual documentation. Professor Marte S. Gulliksen of USN was involved in the study as a co-researcher. The general aim was to develop an understanding of how the picturebook app facilitated or limited sense-making. The first aim was to study and document how interactive elements such as object manipulation and gyroscopic movement foster embodied entanglement and affordances and how this affects perception, experience, and sensory "feel." The second aim was to study and document sense-making with a focus on tactile and haptic perception in interaction with virtual materiality and a virtual environment. The third aim was to develop an understanding of my own movement and sensory experience in interaction with a virtual environment. The focus was specifically on audio-visual documentation and the artistic processes of photography and collage making.

Case 3 involved six children, ages 5–6, and their ECE teacher. This study had similarities with Case 1, which involved ECTE students. The insight from the first case was used to tailor this last case. In this study, I drew on ABR (Barone & Eisner, 2012) and sensory ethnography (Pink, 2015) with audio-visual documentation. The children were invited into a facilitated room. The first aim was to utilize this large-scale project room by inviting children to engage in explorations with similar technologies and materials as in Case 1. My identity as an a/r/tographer was prominent in this process, as I aimed to facilitate their exploration and imagining through the affordances of the material and digital technologies. The second aim was

to capture moments of engagement and the sense-making process when they simultaneously explored physical and virtual materialities, when they combined them, and how they made sense of virtual materiality. The third aim was to capture the processes of their sensory experience with a special focus on their tactile and haptic exploration. The fourth aim was to develop knowledge of arts-based approaches used in understanding children's movements in physical and virtual environments. In the following, I will elaborate on the theoretical foundation touched upon in the introduction.

2 Theoretical Foundation

To develop an understanding of sense-making through explorative touch interactions with physical and virtual materialities, I needed *a theory that includes sensory perception as part of our knowledge making* (Noë, 2006). Thus, this study is informed by embodied cognition theory, which explains how the mind and body are one entity in human experience (Shapiro, 2017). There are different strands of this theory, and in this first section, I explain upon what the general theory of embodied cognition is grounded. I particularly look into the *enactive approach* to cognition by Noë (2006) and, in addition, how interaction plays a crucial role in creating opportunities for perception. In the second section, I describe the *explorative material tradition* and theory of *early childhood education* and the field of arts and crafts in light of embodied cognition theory. From this perspective, children's capacity to understand their surroundings is seen as bodily and affective, dependent on the relationship between their bodies and the environment. Another important aspect of making sense of materiality is how the new experience is connected to past experience, memories, and imagination. In addition to these aspects, in the third section, I look into how emotions give meaning to experience (Johnson, 2007) and are key in the process of sense-making. In the fourth section, I delve into the theory of the senses and especially *into tactile and haptic perception.* I also address how the senses are interrelated – especially how the sense of touch is interwoven with vision (Pusch & Lécuyer, 2011) – to frame a foundation to discuss sense-making in experiencing virtual materiality. Finally, in the fifth section, I go deeper into how *digital technology* can be understood as a tool and a medium. I elaborate on the theory of sensing and exploration of virtual materiality to form a basis for discussing the empirical data of my study.

2.1 Embodied Cognition, Sensing, and Sense-Making

The concept of embodied cognition is relatively new, although different philosophers have argued for a knowing body for almost a century. Over the past 15 years, new knowledge has been developed on how our mind is embodied, enacted through our bodies, and grounded in our senses (Noë, 2006; Shapiro, 2017). Embodied cognition theory suggests that a person's sense-making is grounded in both perception and action, and that cognition is dependent upon a person's sensory experience in an environment (e.g., Fugate et al., 2018, Shapiro, 2017,

Wilson, 2002). This understanding is increasingly entering education, and embodiment in educational science has taken a more central place in recent years (Bengtsson, 2013; Gulliksen, 2017; Kiefer & Trumpp, 2012; Moser, 2014). In the context of this dissertation, I think it is important to emphasize that a child's knowledge through embodied experience is different from that of an adult. This is because a child's brain is not fully developed, affecting, for example, its conceptual understanding (Wellsby & Pexman, 2014, pp. 2–3).

Embodied cognition theory is anchored in the perception phenomenology of Merleau-Ponty (1962/2005) and in American pragmatism (Dewey, 1934/2005; Shusterman, 2004). Recently, cognitive science has drawn on phenomenology (Gallagher, 2017), but traditionally psychology has been the foundation for the theory (Chemero, 2010; Shapiro, 2017). In addition to phenomenology and psychology, embodied cognition is especially researched in the fields of robotics, computer science (Arbib, 2006), and linguistics (Lakoff, 2012). Embodied cognition is influenced by a wide range of disciplines, such as neuroscience (Schilhab, 2017) and enactivism in neuroscience (Varela et al., 1991). Unconnected to embodied cognition theory *per se*, some thinkers and writers in the field of arts and crafts, such as Eisner (2002), Schön (1983), and Sennett (2008), have highlighted embodied knowledge and the role of the body in knowing through and in action. The field of arts and crafts education in the Norwegian context is to a great extent inspired and based on the tradition of these thinkers and writers as well as on the tradition of phenomenology.

Our body is both a subject and an object in the world; it has qualities that enable us to both see and be seen, experience and be experienced, sense and be sensed, touch and be touched (Merleau-Ponty, 1962/2005). *Phenomenology* is a philosophical strand and was initiated by Edmund Husserl early in the 19th century (1859–1938). Martin Heidegger (1889–1976) developed a phenomenology that considers the body and its interaction with the world as the fundamental aspect of being. However, he understood human consciousness as central in creating the meaning of experience. Merleau-Ponty (1908–1961) developed the concept of "phenomenology of perception," based on Husserl and Heidegger's previous ideas (1962/2005). Merleau-Ponty's phenomenology emphasizes the role of the physical body in direct contact with the world and the way we make meaning through sense perceptions. He describes human sensory experiences as the foundation of developing understanding of the world, and the senses as informants in sense-making.

American pragmatism is linked to psychology and discusses physical environment experience as key to human understanding (Dewey, 1934/2005; Shusterman, 1999, 2004). William James (1842–1910), psychologist and philosopher, is considered to be the founder of

pragmatism and one of the first to write about the role of emotions in experience (James, 1884). John Dewey (1859–1952), philosopher, psychologist, and educational reformer, acknowledges the body with its sensory experiences in interaction with the material world as a constitution of an experience. In *Art as Experience*, Dewey (1934/2005, p. 12) places a person's development in close connections with its interactions with its surroundings; "life goes on in an environment; not merely in it but because of it, through interaction with it." He also states that "experience occurs continuously, because the interaction of live creature and environing conditions is involved in the very process of living" (p. 36). Richard Shusterman (1999), a neo-pragmatist who emphasizes the role of *the senses in experience*, describes how a person, through exercise, can learn to direct attention and the senses to the essentials in situations and thus improve the experience. He states, "knowledge of the world is improved not by denying *our bodily senses but by perfecting them*" (p. 302). In arts and crafts education, the influence of pragmatism has been very strong, especially through Schön's theory (1983). He draws on Dewey's understanding of embodied knowledge in action and emphasizes the practitioner's reflection in and on action. In this context, I must also mention Polanyi (1966/1983), who has been and is central in arts and crafts education. He emphasizes how parts of our personal knowledge are tacit knowledge, meaning that it is silent if we do not find ways to explicate it.

The theory on enactivism is compatible with Gibson's (1979) theory of human–environment coupling and understanding of how humans make sense of the world through interacting and exploring it. Gibson (1904–1979), a psychologist, introduced in 1979 the concept of affordances to describe living organisms' relationships with the environment. He argues that the physical environment is important for how all organisms live and learn. He states how our cognition is directly linked to our ability to act, facilitated by the environment affordances (p. 127). He goes on to explain that, through interactions, we develop an understanding of the material, technological, and environment affordances in relation to our capacities. In the context of my study, it is important to mention how the concept of affordances "reflects the intimacy of perception and action" as explained by Michaels and Palatinus (2017, p. 23). The authors describe how affordances "are only part of the perception-action story" and state that two other perspectives are central in this process. The first one is exploration: A person can engage in a variety of actions that make information available through, for example, looking and sniffing – "but it is the haptic sense that most obviously depends on exploratory movements, such as rubbing, hefting etc." (p. 23). Second, they discuss how *"*performatory actions reveal information appropriate for their own guidance" (p. 23). I include this perspective to highlight how perception and action are tightly interwoven and to stress how the haptic sense is especially

important in experiencing the affordances of an environment. I understand exploration and the performatory to be intimacy connected. This also corresponds to how I understand materiality to be a process that refers to our perception, a process that is relationally and performatively conditioned (Damsholt & Simonsen, 2009). The perspective of the intimacy of perception and action also corresponds to how humans do not passively receive information from their environments (Nöe, 2006). I return to this below.

Another central contributor discussing embodied knowledge is Mark Johnson. In his book *The Meaning of the Body*, he argues for an embodied mind and challenges the philosophical tradition of dualism (Johnson, 2007). Johnson's theory is influenced by American pragmatism, phenomenology, and cognitive science. He states, "We are born into the world as creatures of the flesh, and it is through our bodily perceptions, movements, emotions, and feelings that meaning becomes possible and takes the forms it does" (p. x). As early as 1980, together with George Lakoff, Johnson made a significant contribution to describe how the language we used to think is tied to the body (Lakoff & Johnson, 1980/2003). I will return to how language is grounded in our bodily experience of the world at the end of this section.

Embodied cognition theories have developed in two directions, according to Borghi and Cimatti (2009). They note that one direction seeks to ground the extended mind in language and simulation (language grounding); this direction is similar to situated cognition (p. 763). The other direction is more connected to environmental biology and enactivism and underlines the person's active and dynamic relationship to the world and how the mind is shaped by the person's features of the body (p. 763).

In my study, I especially look into the enactive approach to cognitive science. *Enactivism* is described by philosopher and neuroscientist Alva Noë. He describes the connectedness of the organism and the world as an active and dynamic relationship, primarily shaped by the features of the body (Noë, 2006, 2009). In this theory, the role of interaction plays a crucial role in creating opportunities for perception (Noë, 2006). Perception "is something we do" – an explorative interaction – "not something that happens to us," or in us (p. 1). Noë argues, "The world makes itself available to the perceiver through physical movement and interaction . . . , we enact our perceptual experience" (p. 1). This means that perception and cognition are dependent upon our embodied movement and interactions in our environment (see Varela et al. 1991, pp.172–173). Knowing the world is an embodied active process emerging through our *senses of touch*, hearing, smell, vision, and taste, modalities that make our experiences multimodal. We receive sensory information through different types of receptors in our body; we have receptors located in, for example, our ears and in our fingers

that register texture, location, and position (Groh, 2014, pp. 86–88). Sensory information is unavailable to us until it is perceived as vision, taste, sound, smell, tactile, and haptic perception.

Sense-making is a key concept in cognitive science and is especially central in the enactive approach to cognition (Di Paolo & Thompson, 2017). This perspective 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). The body is integral in all knowing because a person makes sense through interaction and accumulates knowledge through their embodied experiences with her environment (Noë, 2006, 2009). In this activity, new and past experiences are combined when the person is engaged in the process of making sense. A central perspective on sense-making within the context of this study is how we make sense together with others in a social and cultural context and combine new and past experience through our interactions in the environment. The term "participatory sense-making" indicates that sense-making can also be a joint effort (Di Paolo & Thompson, 2017, p. 75). When, for example, a group of children touches and explores a material, it is important for me to develop understanding about their joint sense-making. Di Paolo and Thompson (p. 75) acknowledge that sense-making is an embodied process of active regulation of the coupling between a person and the world, and in social interaction – "through patterns of bodily coordination and breakdown" – it opens up the possibility of this process being shared among the interactors. The note that sense-making "happens to various degrees, from orientation of individual sense-making to joint sense-making" (p. 75). Another important aspect related to my study and to education in general is their idea that "through participatory sense-making the enactive approach thematizes preexisting empirical and practical knowledge that has often been neglected by mainstream theoretical framework" (p. 75). In other words, the enactive approach can be key to developing knowledge about sensory perception and embodiment in education.

Emotions and cognition are seen as inseparable in cognitive science; there is no cognition without emotions (Thompson & Stapleton, 2008, p. 26). *Emotions* give meaning to human experience (Johnson, 2007). Our capacity to make sense of our surroundings is "essentially bodily and affective, and capture how the constitution of meaning involved in appraisal depends on the relationship between body and environment" (Maiese, 2017, p. 235). In other words, perception, interaction, and emotions are seen as a unity in a person's experience (Jelic et al., 2016), and emotions play a key role in our process of sense-making. I will come back to this in section 2.3, and describe it more thoroughly.

Humans' embodied minds also manifest themselves in and through language. Lakoff and Johnson's (1980/2003) groundbreaking book *Metaphors We Live By* revealed how our thinking and language are grounded in our bodily experience of the world. Human language is built on metaphors that are closely related to the way we use and inhabit our body; we do this through image schemas (Johnson, 2007, p. 136). Groh (2014, p. 208) describes it with reference to Lakoff and Johnson (1980/2003) in this way: "we utilize sensory and motor-building blocks for abstract thinking via metaphor." The meaning of words is closely connected/linked to spatial sensory-motor processing (p. 207). Because such metaphors structure our most basic understandings of our experience, they can shape our perceptions and actions without us ever noticing them (Lakoff & Johnson, 1980/2003). Gallager (2017) distinguishes between our *body image* and our *body schema*. Body image is connected to one's own perception and body, and a body schema is a conceptual representation of our body's interaction and movement in a space (Gallagher, 1986, p. 543). Gallagher (2017, p. 11) describes it in relation to Merleau-Ponty's phenomenology this way: "I hold my body as an invisible position and I know the position of each of my limbs through a body schema." This system of sensory-motor capacities unconsciously and automatically allows us to, for example, move our body while giving attention to other things (Johnson, 2007, p. 5). These recurring dynamic patterns of perceptual interaction and motor programs give coherence and structure to our experience. Individual words within a language are also often mapped to embodied instances (Fugate et al., 2018, p. 7). Schilhab (2015) describes how language is embodied and that language acquisition is dependent on the experiences of our concrete surroundings. This means that the tools we use to think and the process we use to arrange memories and communicate our thoughts are deeply embodied. In this context, it is important to note that memories are both implicit and declarative, which I come back to in section 2.3.

In this section, I have described the concept of embodied cognition and how different theories have argued for a knowing body for almost a century. In the next section, I will look deeper into the tradition of material exploration in the context of Norwegian ECE.

2.2 Explorations of Materials and Physical Surroundings

Children make sense of the world through interactions with their material and physical surroundings. A child might explore a material like the bark of a trunk of a tree by stretching the hand out to touch the rough surface with their fingers, and by grabbing the trunk, press the cheek into the bark and smell the wood. A child can manipulate the bark by picking it apart and throwing it into a stream to experience what happens when it floats away in running water.

Initially, I described how the focus on material exploration and haptic perception in Norwegian ECE goes all the way back to Fröbel in the 1800s (Carlsen, 2015; Fredriksen, 2011a, 2011b). In addition, I emphasized that children's direct experience with materials is seen as fundamental in arts and crafts education (Fredriksen, 2011a; Pacini-Ketchabaw et al., 2017; Waterhouse, 2013). I also acknowledged that there has been a *material turn* in our society (Barad, 2007) and that a renewed interest in *the meaning of materiality* has emerged (Gregersen & Skiveren, 2016). Based on this, I will now delve into this field as a background to understand children's sense-making processes in the context of digitalization of materiality.

The material turn has gained an especially strong foothold in the so-called new materialism (Barad, 2007; Lenz Taguchi 2010). New materialism draws on different theories from cultural and environmental studies, philosophy, science studies, and others. These theories do not abandon the meaning of the discursive or social, but put the meaning of our material surroundings on the agenda. In relation to ECE, this can be understood as a turn toward a process-oriented–ontological view on learning and a highlighting of experiential knowledge in interaction with our material surroundings. Both Gibson (1979) and Dewey's (1934/2005) theories form a basis for understanding experience in human–material interaction. Gibson's concept of "affordance" offers a framework through which we can understand materials. The term affordance implies that materials provide different resistance and opportunity to different people when they explore, handle, and interact with them (Gibson, 1979). From a Gibsonian perspective, physical exploration early in life furnishes children with a repertoire for understanding the physical qualities of objects and materials (Kiefer & Trumpp, 2012, pp. 19–20).

Embodied cognition theory has, as noted, a strong foundation in American pragmatism (Dewey, 1934/2005), which has influenced arts and crafts education. Eisner (2002) has, as stated, been a central thinker and writer in arts and crafts, which has emphasized the role of embodied knowing in interaction with our material surroundings. Dewey (1897, p. 77)

explained, more than a century ago, that children's interactions and manipulation of materials plays a crucial role in education. He states how sensory perception through interaction with our material environment is a crucial part of our experience, and how art experience often starts with an impulse that meets resistance (Dewey, 1934/2005). He contends that the resistance of materials can invite reflection and, in this way, challenge a person, and that through a person's perception, each material expresses something that cannot be communicated in any other language. Eisner (2002, p. 2) describes human interaction with environments like this:

> Our biological system is designed to enable us to survive – with the help of others. But we also learn. We learn to see, to hear, and to discern the qualitative complexities of what we taste and touch. We learn to differentiate and discriminate, to recognize and to recall. What first was a reflex response, a function of instinct, becomes a gradual search for stimulation, differentiation, exploration, and eventually for meaning.

Through explorative interactions with our material surroundings, we get to know them. Anthropologist Tim Ingold (2013, p. 29) states that "a material is known not by what it is but what it does." Materials can be described as something concrete with features such as density, weight, and form. In an arts and crafts process, it is also meaningful to describe how materials affect us through handling them (Ingold, 2007, p. 14) and how they are part of a relational process. It is easier to describe what materials *are* than what *they do to us.* Fredriksen (2011a, p. 54) notes how the common properties of materials are graspable; they have consistency, mass, texture, temperature, etc. I can, for example, describe a rock as heavy and cold. Such material properties allow us to, for example, move, lift, and manipulate materials, and enable us to interact with them in different ways (p. 54). If we look to *design thinking*, Groth (2017, p. 81) describes how "manipulating material may be seen as a way of being in, and affecting, the world as well as negotiating meaning related to our abilities and limitations." This is a description of what the materials can do to us through handling them. Ingold states (2013, p. 6), "materials think in us, as we think through them" in the "fluxes and flows of the materials with which we work." I acknowledge that to think in and through materials is at the heart of what arts and crafts education is about. However, most of the theory in ECE seems to focus on what children can do with materials, instead of highlighting how *materials think in children* and how *materials can shape the meaning children construct* through interacting with them (Pacini-Ketchabaw et al., 2017, p. 3). Material engagement can be a way to connect to ourselves, to others, and to our environment. Ingold (2011, p. xii) describes how the material

world is "constantly inspiring us, challenging us, telling us things." This means that material engagement requires awareness through interaction and attention to our surroundings. Children's engagement with the material world might not seek specific and concrete answers, but explore possibilities. Kullmann (2016, p. 78) states, with reference to Barad (2007): "knowing does not come from standing at a distance and representing but rather from *a direct material engagement* with the world." I think this statement underpins how important children's tactile and haptic experiences are. Lenz Taguchi (2010) notes how meaning is created in an active space between the material environment and all living organisms. She refers to an intra-active pedagogy that acknowledges a material–discursive relationship, including objects, spaces, and places. Fredriksen (2011a, p. 299) claims that material exploration is a "driving force behind children's self-motivated actions to search for problems and find solutions. Creation of new meanings happens at the core of these explorative actions." Through direct material engagement, children can develop experiential knowledge of the material properties and experience how materials challenge and affect through meaning negotiation.

To understand more about what a material does, I look to Reggio Emilia's philosophy. Carlsen (2015) points in her study to the learning culture, inspired by the atelier culture of Reggio Emilia, as an important aspect of children's material exploration. In this culture, the physical environment has been called "the third pedagogue" (Vecchi & Giudici, 2004). This pedagogy maintains that a child is connected to their environment through the relationship with his/her inner world (emotions, cognition, etc.), body and other objects (materials, digital technologies, indoor space, etc.) as well as the entire environment (outdoor, society, etc.) (Vecchi & Giudici, 2004). Carlsen (2015) also points to children's sensations, curiosity, and resistance when they are interacting with materials. She contends that *materials meet us with new opportunities every time we interact with them* (p. 135). In this process, the time aspect is central: the time it takes to explore a material and be in a material process. She also addresses the challenge that, when the symbolic and communicative are given extensive attention, this leads to giving the visual more attention than the other senses, such as a child's tactile experience of a material (Carlsen, 2015, p. 130).

The surfaces of our surroundings play a key role in how we make sense because it is through them that we experience tactile and haptic perception. In Gibson's (1979, p. 16) work *The Ecological Approach to Visual Perception,* he distinguishes three components of the inhabited environment: *medium*, *substances,* and *surfaces.* Gibson describes the environment as the surfaces that separate substances from the medium in which the organism lives. For humans, the medium is normally air, and substances are concrete materials such as wood and

rock. In the interface between medium and substances are the *surfaces* (see also Ingold, 2011, p. 22*)*. To understand how the surfaces affect us is central in this study, which involves surfaces like a smooth surface of a touch device and rough surfaces like the skeleton of a buck skull. Ingold (2017, p. 99) argues that there is a renewed interest in the surfaces in disciplines such as social anthropology, architecture, and design, and in studies of visual and material culture. The renewed *attention to surfaces* in these disciplines is a way of understanding and treating them, as key conditions for the generation of meaning (Ingold, 2017, pp. 99–100). Ingold (2011, p. 23) made me aware that Gibson's theory of perception is criticized for offering only a weak recognition of the materiality of the world. Ingold (p. 23) states that Gibson's theory so far has failed to address "what an encounter between the fingertip and the materiality of the world might have to tell us of a scopic we call place." My interpretation of this is that there is a potential to deepen understanding of the meaning of affordances and tactile and haptic perception of materiality. In continuation of this discussion, Ingold (p. 24) describes and distinguishes materials and materiality in this way:

> I can touch the rock, whether of a cave wall or of the ground underfoot, and can thereby gain a feel for what rock is like as a *material*. But I cannot touch the *materiality* of the rock. The surface of materiality, in short, is an illusion.

A material can be touched, but the materiality of a material cannot be touched. In the short term, materiality can be described as an illusion (see 1.1.1 for a comprehensive description of the term). A touch device is made of smooth materials like glass without a texture. The surface of a touch device can be touched while the device can be held by hands, as a virtual materiality that is simultaneously untouchable can be made available through the device. I think these addresses the material paradox of virtual realities, and how virtual materialities can be understood to be in the grip of invisible matter (see Browaeys, 2019, p. 5). I come back to this in sections 2.4 and 2.5. In terms of a material context, Fredriksen (2011a, p. 44) points out that textures are the different qualities of surfaces that can be experienced through senses, the tactile and haptic touch. *Surface* can in this way be understood to be important in the process of making sense.

To summarize, children's material engagement is important, especially since it is largely tactile and haptic centered (Carlsen, 2015). A material practice acknowledges that materials can "think" in children and shape their meaning through interactions (Fredriksen, 2011a; Ingold, 2013). In this context, the time aspect provides opportunities for material exploration, which in

many ways may be considered as an opposite to the logic and effectiveness of digital technologies. This might address challenges in the context of facilitating sense-making. In this section, I have also addressed the material paradox of virtual realities. Given that surfaces can be understood to be key conditions for making sense (Ingold, 2017), this can, in addition, address challenges within digital technologies such as touch devices, which might be understood to be a materiality with a passive response to tactile stimuli. In the next section, I turn my attention toward emotions, memory, and imagination in sense-making processes.

2.3 Emotions, Memory, and Imagination

Emotions are essential for our capacity to make sense, and they are crucial in giving meaning to our experience (Johnson, 2007, p. 66). Emotions are both a part of our body and in us, at the same time as they are a process of our environmental interactions (Johnson, 2007, p. 66). In this way, sense-making can be understood to be a "*bodily-cognitive-emotional form of understanding*" (Colombetti, 2007; Maiese, 2017, p. 236). Emotions involve "perceptions and assessments of situations in the continual process of transforming those situations" (Johnson, 2007, pp. 66–67). Emotions are often experienced before there is abstract thinking, and we are able to understand why, for example, a taste gives us a distinct feeling (p. 52). An example of this is how a taste can bring back a memory from childhood, and emotions can be felt before you remember that it is, for instance, the taste of your mother's meatloaf that brings back these emotions.

I understand *emotions to be enactive* and, in line with Maiese (2017, p. 231), and as sense-making faculties "of the whole embodied and situated organism." Emotions as enactive means that they are enacted in our bodies in interaction with the environment and "they are ways of engaging with and make sense of the world" (Maiese, 2017, p. 231). Our *living body* serves as the spatial point of emergence of all emotional experience (p. 233). This stresses how emotions are tied to our living and moving bodies in interaction with the environment. The concept of "the living body" stems from the tradition of Merlau-Ponty (1962/2005). I understand emotions, perception, and environment interaction–coupling as fundamental in a person's experience; in this process, both the conscious and unconscious capacities play a role (Jelic et al., 2016, p .6). Newer theory on embodied cognition outlines that the living body and its corresponding neurobiological dynamics play a constitutive role rather than only a causal one in emotional experience (Maiese, 2017, p. 231). However, most cognitive scientists involving an embodied view of the mind have not adequately investigated the role of emotions

(Colombetti, 2007, p. 528). There is a tendency to understand bodily instances as an objective index of emotion, rather than as processes of a lived body (p. 528). This underpins how important it is to highlight the bodily–cognitive–emotional form of understanding in education.

Our emotional experience is *closely tied to our bodily feelings* of different bodily changes such as a racing heart or tingling skin (Maiese, 2017, p. 232). Emotions are a central part of experiential states that are "bound up with bodily feelings of pleasure and displeasure" (p. 233). Emotional associations are closely linked to perception because the way we feel toward something influences what sensory information we seek out and interpret. Our emotions can also be influenced and affected by looking at someone performing an action. Through looking, we can empathize with and learn from others. This can be explained by the mirroring system (Rizzolatti & Craighero, 2004). How emotions influence the sensory information we perceive can deepen understanding of how we perceive and make sense of, for example, a virtual materiality.

To understand more about sensory experience and emotional associations, we must look closer at *the meaning of memory* and the *reenactment of past experiences in memory*. Humans have at least two different systems for the storage of information (Purves et al., 2012, p. 695), and our memories can be both unconscious and conscious. We process and store memories based on how we experience, sense, understand, and emotionally feel them (Schilhab et al., 2018, p. 2). *Implicit memory* evokes and utilizes emotions without our conscious attention and affects and directs our attention and senses (Maiese, 2017, p. 231; Willems, 2017, p. 35). Such memories involve skills and sensory perception that are largely received and retrieved at an unconscious level (Purves et al., 2012, p. 695). In addition, memory involves a reenactment of past perception (Gallagher, 2017, p. 10). *Declarative memory*, or what we can remember explicitly, encompasses our emotions in episodic memories and how we recall previous experiences (Dijkstra & Zwaan, 2017, pp. 296–298; Purves et al., 2012, pp. 698–699). Knowledge can be "reenacted (i.e., simulated) through the perceptual and sensory systems (e.g., auditory, visual, motor, and somatosensory) such that thinking about an action can evoke the same visual stimuli, motor movement, and tactile sensations as during the act itself" (Fugate et al., 2018, pp.1–2). When a child stretches out his or her arm to touch the bark of a tree, memories of, for example, similar tactile and haptic experiences and emotions can be evoked before the hand touches the tree. This simulation happens on both a conscious and unconscious level. When a child remembers his or her past interactions, it involves making them present again, although in a modified sense from the actual experience (Gallager, 2017, p. 10). Fugate et al. (2018, p. 6) describe the importance of a child's rich action outcomes and that "the more the

initial information engages the sensory and motor cortices, the richer the simulation, and ultimately the better the recall and use of the material." This might mean that children's rich sensory experiences from the material world are essential to make sense of a virtual materiality, which is understood to be an illusion.

When studying sense-making processes in interaction with virtual materiality, it is important to look into the spatiotemporal aspects of memory. A memory can only be presented in a first-person perspective connected to how it was sensed and experienced in time and space (Schilhab et al., 2018, p. 2). Emotional feelings are *temporal* (Maiese, 2017, p. 233). This is because emotions involve a sense of being anchored in the past and situated in the present. Emotions influence perception because the body is a vehicle of memory (Shapiro, 2017, p. 5). Our sensory perception is constantly being filtered, and our emotions play a key role in this process (McAlonan et al., 2008, p. 391). Our memories are an indispensable part of developing a sense of space (Groh, 2014, p. 189), and much of the information we store is intrinsically spatial.

Imagination is part of the process of connecting past and present experiences (Fredriksen, 2011a). Our imagination is linked to both our implicit and our declarative memory, which means that our imagination is part of and incorporated in our bodily process (Johnson, 2007, p. 13). Our mentally picturing (Groh, 2014, p. 205) or our imagination of, for example, sitting on our own couch might be implemented by partially activating tactile and motor responses that would occur if we were actually doing it. This means that imagination is cognitive and experiential (body-based). In addition to memories and perception, imagination plays a key role in our new experiences. Gibbs (2006, p. 64) describes perception in this way: "each case of perception involves someone imagining what it would feel like to touch an object, grasp it with the hands, turn it over, bite it, smell it, and so on." To summarize, if we visually experience a virtual materiality of, for example, a picture of wool on a touch device, we can, through our tactile and haptic memory, emotions, and imagination, recall the feeling of touching wool even if we are not in contact with it. In the next section, I will go deeper into the sense of touch and how our vision is connected to our tactile and haptic perception in order to make a foundation for understanding how we make sense when we experience different materialities.

2.4 Sense of Touch and Haptic Visuality

In this section, I will go deeper into describing the sense of touch, and how the senses are interrelated (O'Regan & Noë, 2001, p. 940), with a special focus on touch-to-vision. How we

use the word touch implies that our emotions are deeply integrated in our understanding of it; we say, for example, that "we keep in touch," "I was touched by his performance," and we can be "emotionally touched." In the introduction of this dissertation, I emphasized that our sense of touch is fundamental to how we develop and experience the world and make sense of it (Field, 2001; Jewitt & Leder Mackley, 2019; Paterson, 2007, p. 2; Springgay, 2008). Touch is considered to be such an important part of our perception that Noë (2006, p. 2) argues that touch, and not vision, should be our model for perception. The sense of touch involves a wide spectrum of different touch perceptions, such as active and passive touch. As Willems (2017) writes, with reference to Merleau-Ponty:

> Grasping the world happens on different levels of the sensible, as I both have a body that can be touched and I am a body that can do the touching: the body is the medium through which I experience the world and I experience my body via that world (p. 26).

In this study, I understand *tactile perception* as physical contact through our skin (i.e. through sensory receptors in our skin) like when someone touches us. *Haptic perception* involves our position, state, and movement of the body and limbs in space, such as when we grasp someone's hand or move through a space (Paterson, 2007, p. ix; Søyland & Gulliksen, 2019, pp. 2–3). Tactile feelings of softness or texture are defined by specific patterns of experience one has when engaging in such activities as stroking wool or pressing the cheek into the bark of a tree (Myin & Degenaar, 2017, p. 91). Haptic perception is directly linked to the possibilities to act, which the environment offers (Gibson, 1979), and gives us the basic experience of being in relation to the environment (Johnson, 2007, p. 50). Our surroundings inform us of what we can do and see, "while at the same time, our perceptual abilities and capacities for skillful action play a role in demarcating—thus, perceiving and potentially engaging—with what is in our world" (Jelic et al., 2016, p. 18, with reference to Ward & Stapleton, 2012).

Touch can be present and play a role without there actually being any touching. Touch can be described as "a proximal relation with something" (Springgay, 2008, p. 21). An example of this is how tactile stimuli can be evoked before the hand touches, for example, a tree (see the example described in 2.2). In such a context, our emotions, memories, and imagination play a part. Another important part of such experiences is how our senses are interrelated. That our *senses are interrelated* means that they operate in relation to each other (O'Regan & Noë, 2001,

p. 940). Gibson (1979, p. 279) describes this as follows: "We do not only see the environment with our eyes, but with the eyes in the head on the shoulders of a body that gets about."

There are different theories that describe how vison and touch are interrelated. I use the term *haptic visuality* to describe this further in the text. Marks (2000) considers a form of haptic visuality in her book *The Skin of the Film*. She emphasizes how memories of embodied experience, such as tactile and haptic perception, can be evoked through the medium of film (p. 162). Ingold (2017, p. 101) describes the haptic experience of running a hand over the surface of a cloth and how it involves feeling the texture, bumps, and folds. He asks if the haptic is limited to the hand and if vision can "be as haptic as manual touch?" Further, he emphasizes that there can be "*optical touch* as well as *haptic vision"* (p. 101).

I will now turn my attention to how haptic visuality is explained within embodied cognition theory. I understand the experience of haptic visuality to some extent provides a passive response. I express it like this because, basically, I understand vision to be active, which is in line with Groh (2014, p. 11). See also my statements about vision at the end of this section. Borghi and Cimatti (2009, p. 765) have been concerned with both passive and active response. They pointed out a decade ago "that current embodied cognition theories focused mostly on overt action, and that they tend to overlook the importance of "passive" responses to environmental stimuli." This may indicate that passive responses like haptic visuality may not have received as much attention in embodied cognition theory. However, there are researchers who look into passive response as "optically simulated haptic feedback" (Pusch & Lécuyer, 2011, pp. 1–2). Theories of haptic visuality are especially important to look into when I am studying sense-making in interaction with virtual materiality, which I understand to be a materiality with a passive response to tactile stimuli. Haptic visuality describes how previous memories of tactile and haptic experience can be triggered by visual feedback and create an illusion of haptic experience (Pusch & Lécuyer, 2011, p. 57). In this context, the haptic percept is different from a physical haptic experience. The theory of haptic visuality is in line with how I have described the senses as interrelated and how memories of tactile and haptic perception can be triggered by visual information and create an experience of haptic visuality – an illusion of tactile and haptic stimulus. Groh (2014, p. 189) stresses how our sense of space is deeply rooted in our combined interpretation of what we see, where we are, and what we are doing. She also describes how it can be provoked or triggered through cross-sensory linking such as tactility-to-vision and movement-to-vision (p. 189). When we, for example, walk through a building, there is not only a correlation between vision and touch but also a connection, through the combined somatic senses, to the sensation of movement of our body and limbs, our

perception of the position, state, and movement of our body and our perception of balance, for example, our head position. In line with what I described about memory in the previous section, such an experience of walking can be reenacted and triggered by, for example, interaction with a touch device and through experience of virtual materiality.

I will now go deeper into *vision* to understand more of how it is interrelated with the sense of touch. I will start with that point that touch is more immediate than vision. The reason why vision is slower than our sense of touch is because "the conversion of a physical stimulus into an electrical response doesn't involve so many intervening steps" (Groh, 2014, p. 20). In line with the enactive approach (Noë, 2006, p. 1), seeing is something we do to the world, rather than something the world does to us (Groh, 2014, p.11). Vision is active and explorative through interaction with the world and is mediated through, for example, our sensorimotor contingencies (O'Regan & Noë, 2001, p. 940). As noted by Myian and Degenar (2017, p. 91):

> Seeing is conceived of as an "exploratory activity" "attuned to" sensorimotor contingencies, or ways in which sensory stimulation changes with movement – such as when a retinal image changes when one walks around an object. Seeing a scene or an object is, in the sensorimotor approach, comparable to felling a surface or object, where the experience is of the whole surface or object, despite the fact that momentary tactile stimulation is limited to the fingertips making contact only at particular places.

A virtual object or a virtual materiality can be experienced through sensory neurons in our eyes that are translated into electrical signals and interpreted as something. This understanding is fundamental in Groh's (2014, p. 69) theory. According to Groh, our stereo-vision (3D) is created when light molecules, traveling in a straight line, trigger receptors in each eye's retina, which forms an image, similar in principle to how an image is created in a camera obscura (p. 25). This image is forwarded into the visual cortex as a *brain map*, and the brain uses space within the brain to make a representation of the outside world (pp. 69–70). Our somatosensory input is similarly mapped out: different areas in the brain make representations of where our hands are and where our body is positioned. Interpreting sensory input like this is a learned cognitive skill, developed throughout our entire life span, through repeated interaction with the physical world and the memory of this interaction (p. 5).

In this section, I have described how our sense of touch is both passive and active, both tactile and haptic. I have also described how our senses are interrelated (O'Regan & Noë, 2001, p. 940) and that memories of tactile and haptic perception can be triggered by visual information

and create an experience of haptic visuality (Pusch & Lécuyer, 2011, p. 57). In the next section, I delve into describing how we make sense through our interaction with digital technologies of both material and virtual objects and environments.

2.5 Digital Technologies: Making Sense of Material and Virtual Objects and Environments

I have described digital technologies as tangible objects made of materials, in addition to being a medium and a tool. A digital technology such as a touch device is a piece of physical hardware that functions as an interface between a person and the software. The software makes interactivity and mediated virtual materiality available through the device. I have previously explained how memories, emotions, and imagination are integral to experience virtual materiality, and how we can engage with haptic visuality – which can be an illusionary tactile and haptic experience – through vision. Now, I go deeper into explaining how digital technology can shape our experience of the world and how our cognition can be extended into a virtual environment. I start by looking into the term mediating tools.

Mediating tools (Säljö, 2006, 2010; Vygotsky, 1978) play a role in how we make sense of our surroundings. Säljö (2010, p. 55) describes how digital technologies do not merely support learning; they transform how we learn. This transformation can present new opportunities, but Säljö also expresses a concern that the transformation can have quick and dramatic ways of influencing education. One of the reasons for this can be because tools mediate cognitive activity and are deeply entwined with our bodies. If we look into Merleau-Ponty's (1962/2005, pp. 146–152) explanation of tools, we see that he describes them as integrated into our own body space, like the blind man's cane. The tool, like the cane, is thus a part of our perceptual field, and we can perceive sensory experience through using it. I understand this as perception as being extended through the "body" of an object or tool. Gibson (1979, p. 41) describes objects as tools as "a sort of extension of the hand, almost an attachment to it or a part of the user's own body." I consider digital technologies to be material objects with characteristic affordances, and through interaction, the act of perception, the ability of a person, and the features of the environment play a part.

We embody technology, and through its mediating capacity, we can experience things that would otherwise be impossible. Don Ihde (2012, p. 376), a post-phenomenologist and philosopher of science and technology, describes how mediators may expand our awareness of a "phenomena which lie beyond human sensory capacities." In this way, mediators can shape

our experience of the world, rather than represent it. An example of this is how a macro lens can enable us to experience other aspects of the world than we can with only our eyes. Perceptual extension is not limited by the outline of a person's body or the surface of a person's skin (Ihde, 1990, p. 40). Digital technologies as mediators can modify our time perception and our experience of space (spatiotemporal) (Browaeys, 2019, p. 7; Elleström, 2011, p. 36). Browaeys (2019, p. 7) describes mediation as being "caught in a net of knowledge which blurs our original human perception." An example of this is how digital technology can make us experience the world mediated in slow motion. Another example is how we can enter a virtual space that has different conditions than what is possible to experience in a physical environment; this could be, for example, to walk on the ceiling or to fly through a starry sky. A mediator can transform what we perceive and reduce other aspects of our perception.

Finally, in this theory chapter, I *present a table that summarizes* what material and virtual objects and physical and virtual environments are and how we experience them (Table 1). It is a summary of the concepts I have presented in this chapter and how they are understood and used in this dissertation. The bullets to the right of the table are explanations of what the boxes on the left briefly describe. I will now explain the central points of the table. We experience *material* and *virtual objects* in different ways. A material object is tangible and can be held in hand, while virtual objects are illusions of objects with illusionary material features (e.g., texture). Studies show that when a person is asked about a specific object, he or she will often imagine the use or the action features of that object (Fugate et al., 2018, p. 5). Similarly, when persons are asked about tools, they will often think about "physically manipulating them as if they were actually using them" (Fugate et. al., 2018, p. 5). This underlines how the experience of virtual objects can be bridged to previous tactile and haptic experiences and be an experience of haptic visuality.

In this study, I relate to two different kinds of *virtual environments* (Table 1). The first involves a virtual environment made available through a virtual reality app, and the second involves a virtual environment made available through projection. I now describe the first one, which is a virtual environment mediated through the physical device and the software program. In this first type of virtual environment, the movement of the body in the physical environment in interaction with the software becomes a part of the virtual environment experience. This can be exemplified by moving the body when holding a device in the hands over one's own head while at the same time looking into a virtual forest and up into a virtual sky. In this context, I understand the role of simulating the action and perception of past experience as central. This means that memories can more easily be recalled when assuming the bodily positions and

postures that are similar to those of the original experience during the remembered experience (Dijkstra & Zwaan, 2017, pp. 297–298). In this way, the movement in the physical environment in interaction with a device and the software can be an essential part of making sense of the new experience. In the second, the virtual environment is mediated through projection. When a photo is projected onto the surface of a room, it is possible to move "into" and "touch" virtual materiality in space. A virtual materiality can be experienced during this projection onto a three-dimensional object, so it is possible to move it around, but this kind of virtuality is not three-dimensional (e.g., a hologram projection).

Related to computer gameplay, Susi (2017, p. 3) suggests "ways in which *cognition might extend into* physical and virtual *environments*." That our cognition is extended means that we offload meaning onto external objects and onto the environment (Wilson, 2002, p. 626). But how can we offload meaning into something that is does not physically exist? The brain uses "space within the brain to represent information about space in the physical worlds or body" (Groh, 2014, p. 70). I understand this as the brain interpreting sensory impressions and making mental representations of a 3D space. In line with what has been described in the previous section, memory and imagination are linked to brain maps of space. This means that memory is situated in previous experience developed through our past movement, and in this way it is an important factor in understanding ourselves in relation to our environment (Groh, 2014, p. 5). I understand this to be an important factor as well in relation to our virtual environment. In a person's bodily movement in virtual space, the body is a resource for his or her "cognition in a tightly coupled action-perception loop" (Susi, 2017, p. 188). Susi further discusses how the gameplay experience emerges not just between the player and the game but rather "from a unique interaction process that cuts across different aspects of embodiment" (p. 192). In this context, the role of "imaginative immersion," which refers to the use of imagination to empathize with the virtual environment, is central (p. 192). To summarize, mediators can shape our experience of the world and expand that experience beyond our sensory capacities. However, an experience of a virtual materiality will always be a reduction from a full body experience in a physical environment. In the next section, I present a theory synthesis.

Table 1. Material objects and physical environments and virtual objects and virtual environments.

Material objects and physical environments	
Material objects in our physical environment	- We are materials; our bodies are material and have a materiality that we can experience. - Our surroundings are material, and everything that surrounds us has a materiality that we can experience through our perception (in this context, I also include the materiality of, for example, light and sound). - Our material surroundings include objects. These can be artifacts and delimited parts of the physical environment, including touch devices and projectors. All objects have a physical materiality that we can experience. - Material objects such as touch devices and projectors consist of hard materials, soft materials, electrical circuits, intangible materials like light, glass, etc.
How material objects are used and experienced	- Objects can be produced by using some kind of technology. - Objects are part of the physical surroundings which we navigate and interact with. Objects can be used to produce physical objects, artifacts, and digital content, such as multimedia products or expressions, or to experience digital content as multimedia expressions. - Objects are experienced through sensory perception – they can be manipulated by hands and by moving around them in an environment.
Virtual objects and virtual environments	
What virtual objects are	- Virtual objects can be illusions of objects (in an environment, on a screen). - Virtual objects can be illusions of materials (in a room via projection, on a screen).
How virtual objects can be experienced	- Through vision and movement in surroundings: A virtual materiality can be an experience projected onto a three-dimensional object, so it is possible to move around in a physical space; this kind of virtuality is not three-dimensional such as a hologram projection. - Through vision on a touch device screen, through navigation on screen.
What virtual environments are	- Illusions of physical surroundings in an environment (projection onto a physical three-dimensional object – environment, projected hologram) or on a screen in a virtual room/environment. - Illusions of three-dimensional space (on screen – in physical room).
How virtual environments can be experienced	- Virtual environment mediated through projection. When a photo is projected into the surface of a room, it is possible to move “into” and “touch” virtual materiality in space.

	- Virtual environment mediated through a physical device and its software program. Bodily movement in the physical space in interaction with the device and the software becomes a part of the virtual environment experience.
How virtual objects are used (there is a producer that has produced these objects)	- By the producer: to produce illusions of objects, artifacts, materials, for the environment or for screen. - By the user: through interface navigation. Depending on who has the control, for example, when I moved the projection in interaction with the children.
How a professional (e.g., software designer) produces virtual objects	- They are programmed in digital technology with binary code.
How a user can produce virtual objects	- By using digital technology to take photos, capture video, use time-lapse, create a drawing, make an animation, etc. Use a macro lens in taking photos and capturing video. Projection into an environment – projection on bodies, things, artifacts, materials.

2.6 Theory Synthesis

Four hundred years have passed since Descartes presented a theory that separates the mind from the body. Since then, there has been a turn toward accepting the mind as embodied in cognitive science, in arts and craft science, and in educational science. The embodied cognition theory is relatively new but has a strong foundation in the perception phenomenology of Merleau-Ponty (1962/2005) and in the tradition of American pragmatism (Dewey, 1934/2005). Embodied knowledge has also been emphasized by Gibson's (1979) theory of human environment interaction. The enactive approach to cognition describes how our minds are enacted through our bodies and grounded in our senses, and perception is seen as something active – something we do (Noë, 2006). Sense-making is a key concept in cognitive science (Di Paolo & Thompson, 2017) and describes how cognition functions is 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). Moreover, sense-making can be a joint undertaking among interactors (Di Paolo & Thompson, 2017).

Children's material engagement is important, especially since it is largely tactile and haptic-centered (Carlsen, 2015). *Material exploration* in Norwegian ECE has a tradition that

goes back to Fröbel in the eighteenth century (Carlsen, 2015; Fredriksen, 2011a). The material tradition has a strong foundation in the work of Dewey (1934/2005) and Gibson (1979). In recent years, Barad (2007) has stressed that materials matter in human–environment intra-action, and Ingold (2007) emphasizes the importance of the tactile in interaction with materials. The material practice acknowledges that materials can "think" in children and shape their meaning through interactions (Fredriksen, 2011a; Ingold, 2013).

Emotions and feelings are essential for our capacity to make sense (Thompson & Stapleton, 2008). Emotions are closely tied to our bodily feelings, and perception is closely linked to emotional associations (Groth, 2017). We can re-enact experiences of implicit and declarative memory (unconscious and conscious), which is fundamental to how we make sense of a virtual materiality. New experiences can be simulated through memories and perceptual and sensory systems (Fugate et. al., 2018). Imagination is tied to our bodily process (Johnson, 2007), and memories and imagination involve making the past and present sensible in a single moment (Willems, 2017; Gibbs, 2006).

Our *sense of touch* is fundamental to our ability to make sense of the world. Through tactile and haptic touch, we can make sense of ourselves in relation to our surroundings. Our senses are interrelated (O'Regan & Noë 2001, p. 940). They always operate in relation to each other; for example, our sense of space is deeply rooted in our combined interpretation of what we see, where we are, and what we are doing (Groh, 2014). Haptic visuality explains how memories of tactile and haptic perception can be triggered by visual information and create an experience of an illusion of physical materiality – a virtual materiality. Memories of tactile and haptic perception can be triggered by visual information and create an illusion of haptic experience (Pusch & Lécuyer, 2011, p. 57).

A mediating tool (Säljö, 2006) such as a digital technology can shape our experience of the world and expand our awareness of phenomena that lie beyond human sensory capacities (Ihde, 2012). We experience *material* and *virtual objects* in different ways, and cognition can be extended into a *virtual environment*. This can be explained by how the brain understands sensory impressions and makes mental representations of a 3D space (Groh, 2014) and by the theory of haptic visuality (Pusch & Lécuyer, 2011).

3 Research Questions

The guiding research question of this study is:

> *How can explorative touch interactions with physical and virtual materialities facilitate processes of sense-making?*

The specific sub-questions for the different cases are:

Case 1:

> *[What happens when we open up to experimental and unforeseen processes that transform physical and digital materials and phenomena into creative processes?]*

Case 2:

> *How is touch interaction with a picture book app facilitating or limiting sense-making?*

Case 3:

> *How do young children make sense of the world through explorative touch interactions with physical and virtual materialities?*

Case 2 and 3:

> *How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations?*

The guiding research question of this study is: *How can explorative touch interactions with physical and virtual materialities facilitate processes of sense-making?* I considered the case study in the tradition of Robert Stake (2010) as a relevant approach to studying sense-making. The study consists of three case studies, each with a research sub-question (Table 2). The sub-question in Case 1 is answered in Publication I, the sub-question in Case 2 in Publication II, and in Case 3 in Publication III. The fourth sub-question in Cases 2 and 3 is answered in Publication IV. These questions are answered in their related publications, as shown in Table 2. The original publications I–IV are also listed on page ix. A research process is a changing and developing process, and the research questions reflect my understanding and knowledge at different stages in the study. During the process, the research questions have been modified.

The use of concept was made clear through working with this dissertation (see 1.1.1 for key concepts of the study).

Table 2. The study cases, sub-questions, and publications.

Case 1	Case 2	Case 3	Cases 2 and 3
Sub-question 1:	**Sub-question 2:**	**Sub-question 3:**	**Sub-question 4:**
What happens when we open up to experimental and unforeseen processes that transform physical and digital materials and phenomena into creative processes?	How is touch interaction with a picturebook app facilitating or limiting sense-making?	How do young children make sense of the world through explorative touch interactions with physical and virtual materialities?	How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations?
Publication I:	**Publication II:**	**Publication II:**	**Publication IV:**
"Experimental Explorations of Materials and Materiality in Transmaterial Landscapes"	"Sense-making through Touch Interaction with a Picturebook App"	"Children's Sense-making through Exploration: Grasping Physical and Virtual Materialities"	"Making Sense of Movement: A/r/tographic Explorations of Physical and Virtual Environments"

4 Research Approach and Methods

Studying how explorative touch interactions with physical and virtual materialities facilitate processes of sense-making provides a setting for studying the interaction between the embodied mind and the environment. This present research study comprised three case studies, which provided an opportunity to study three different contexts of sense-making through explorative interactions with different materialities. I first gained a deeper understanding of what happens when a group of ECE student teachers and three a/r/tographers explore different materials and materialities. Second, the focus was turned to studying my own explorative touch interaction with a virtual picturebook app. Finally, I turned my attention to studying a group of young children's sense-making through exploration of physical and virtual materialities.

4.1 General Orientation of the Research

4.1.1 Epistemology

Epistemology frames our assumptions of "how we know what we know" (Crotty, 1998, p. 8). This dissertation is positioned within an epistemological perspective that acknowledges our embodied minds (Fugate et al., 2018). I build on an understanding that we develop knowledge and make sense through our minds, which are rooted in the bodies' sensory experience and interaction with the environment (Noë, 2006, 2009). Sensory experiences are essential in the development of knowledge, especially in children, because their embodied minds are developing at a rapid rate when they are young, and they have more to learn than adults. This perspective, which highlights that knowledge arises through embodied interaction with the material environment, is strong in the arts and crafts ECE tradition and the traditions of Dewey, Merleau-Ponty, Gibson, and Ingold.

4.1.2 Personal Background and Motivation

From an early age, I was interested and engaged in explorative material processes. I grew up in the countryside in the 1980s, and my world was a world of material explorations. From 1998 to 2006, I attended two different arts and crafts schools and took bachelor and master's degrees in educational design, arts, and crafts. I have taught educational arts and crafts to children, youth, and adults since 2006. I have worked as an artist, teacher, and researcher in higher education since 2011. Through my first years of teaching, I experienced that many students and colleagues who were concerned about materials were critical of digital technology's existence

and considered it a potential threat. Those who worked with digital technology were, in a sense, accepting of its logic and excited about its potentials, and were generally not critical to it at all. I experienced that there was little space in-between this kind of polarizing environment. It seemed like very few were concerned with the potentials and/or challenges of what could arise in the meeting between materials and digital technology, or exploring what significance one has for the other. An interest in this emerged in me. With the introduction of touch screens in 2010, new opportunities became available with mobile, handheld touch devices. In addition, new challenges arose related to how touch devices would affect children's sensory experiences and development. This triggered my attention. For me, arts and crafts education is a natural place where materials and technology meet, and a good context to study this. This project is based on an understanding that the combination of materials and digital technologies can provide meaningful experiences, potentials, and discoveries.

4.1.3 Academic Tradition

The Nordic tradition of doctoral studies in arts and crafts education is affiliated with the making disciplines. These disciplines are part of the creative fields that include art, craft, design, architecture, etc. The making disciplines have been under development in Norway since 2000, and this effort has been led by Professor Halina Dunin-Woyseth (Dunin-Woyseth & Nielsen, 2004). The USN, where I work, has a long tradition within arts and crafts teacher education. In 1976, a master's program was established for a major in arts and crafts. The master's program is both educational and academically oriented. The program ranges from kindergarten to primary and high school. This perspective is a part of the epistemic tradition developed in the field of arts and crafts education, especially centered on the practical and academic tradition developed at USN in Notodden, Norway (Gulliksen, 2006; Halvorsen, 1996; Solberg, 2017). In this tradition, the first-person experience is central in developing knowledge.

The program I have attended during my doctoral study at USN is Pedagogical Resources and Learning Processes in Kindergarten and School. There is close cooperation between this program and the doctoral program Cultural Studies at USN. One of the pillars of the doctoral program Cultural Studies was developed as an offshoot resulting from the long tradition of the Master's in Design, Arts and Crafts at Campus Notodden of USN. I am also a member of the Embodied Making and Learning (EMAL) research group led by Professor Marte S. Gulliksen. Through EMAL, we aim to develop knowledge that can explain embodied making practice and understand the body's role in individuals' learning and today's society. Gulliksen has been one of my supervisors through this doctoral dissertation and co-authored Publication II. The close

collaboration between the doctoral programs and membership in the research group EMAL has opened up opportunities and motivated me to study sense-making in an arts and crafts educational context.

4.1.4 Arts-Based Research Methodology and Methods

This dissertation is positioned within an ABR methodology (Barone & Eisner, 2012), and during this study, I have drawn on inspiration and concepts from the arts and involved making processes as part of my study. ABR can be understood to be a methodological field within the qualitative paradigm, while others argue it to be its own paradigm (Leavy, 2019, p. 4). Visual methods are a central part of ABR and have been growing in popularity among social researchers across a wide range of disciplines in recent years (Holm et al., 2019; Rose, 2016). In qualitative research, researchers work toward complexity and search for possible meanings and ways of understanding (Stake, 2010). The aim of ABR is primarily to ask new questions, make new discoveries, and develop new understanding and insight (Dyrrsen, 2010, p. 223). ABR methodology allows for a more flexible interaction between practice and theory than traditional methodologies (Dyrrsen, 2010). ABR opens up the possibility of using innovative and creative methods and has been found particularly helpful in producing valuable data in the context of children's use of digital technologies (Knight, 2019, p. 311). Within ABR, researchers are "living their practices, representing their understandings, and questioning their positions as they integrate knowing, doing, and making through aesthetic experiences that convey meaning rather than facts" (Irwin & Cosson, 2004, p. 31).

Qualitative research is characterized by being "interpretive, experiential, situational and personalistic" (Stake, 2010, p. 15). I have developed an understanding of embodied sense-making in an educational context, especially through my identities as an artist, teacher, and researcher. As described in the introduction, I related my research to ideas from a/r/tography during this study (Irwin et al., 2019). My contribution of knowledge is created through this position and in relationship to these identities. The understanding developed in this study is colored by my personal experience and reflection (Stake, 2010, p. 56) and by my professional background and stands in relationship to the study's epistemological position. Stake (2010, pp. 62–63) argues that, when interpretations are enriched by the researcher's personal experience, understanding of the complex processes can become possible. Subjectivity is seen as an essential element in developing an understanding of human activity (Bresler, 2006; Stake, 2010, p. 29). As a researcher, I will always be situated within the context of my research, and I consider that objectivity is impossible. This makes transparency crucial to being trustworthy

(Stake, 2010, p. 15), and because of who I am, all the choices I make during my research affect the outcome of the research. I used different arts-based methods to develop an understanding of what characterizes my own and others' sensory experiences. However, as a researcher, I can never know what others feel and think but can only imagine and suggest what characterizes their experiences. I took an active and explorative position during the three case studies. Through exploration, I actively used my senses, memories, and emotions to seek understanding. Through this approach, I was able to generate rich and complex data. The methodology of this study was developed through my reading, exploration, observation, making, reflection, and discussion. I have actively searched for and read theory within the epistemology of this study through the four years I have worked on this dissertation. Table 3 presents an overview of the methodology of the study.

Table 3. Methodology of the study.

Epistemology	An epistemological perspective that acknowledges our embodied minds (Fugate et al., 2018; Shapiro, 2017). We make sense through our minds, which are rooted in the bodies' sensory experience and interaction with the environment (Noë, 2006, 2009). Embodied cognition theory influenced by the neuroscience discipline (Schilhab, 2017) and enactivism in neuroscience (Noë, 2006).
Academic tradition	Making disciplines (Dunin-Woyseth & Nielsen, 2004). The epistemic tradition developed in the field of arts and crafts education at USN (Gulliksen, 2006; Halvorsen, 1996; Solberg, 2017). Sense-making in the field of craft (Groth, 2017).
Research context	Arts and crafts education research. ECE research.
Methodology and methods	ABR methodology (Barone & Eisner, 2012), a/r/tography (Irwin et al., 2019), sensory ethnography (Pink, 2015), and explorative inquiry (Dyrssen, 2010). Think-aloud accounts, diary questions, observation notes, retrospective reflection. Visual methods (Rose, 2016), photo and video documentation (headband and overview camera), video analyses, making of digital collages.

I will now describe a general orientation of the methodology of this study. In the next section, I will explain the overview of the research setting in the three different cases. The concept of case study inspired by Stake (2010) has been especially useful in planning, framing, and developing understanding of the phenomena being studied. A case study is a relevant approach to studying the complexity of human experience (Stake, 2010, p. 65). Through tailoring, a case study data can be constructed; it is not coincidental; the tailoring is about the researcher's choices, experiences, and ethics and an aim for making new understandings (Stake, 2010, pp. 83–86).

In this study, *a/r/tography* (Irwin et al., 2019) and sensory ethnography (Pink, 2015) are considered two perspectives that have similarities and are woven into the ABR methodology.

They have similarities and differences through which a person's experiences can be understood and made available. A/r/tography is a form of practice-based research that is well suited to my study of explorative interactions. A/r/tography in this study is seen as a tool to study educational phenomena through an artistic understanding and inquiry process (Irwin et al., 2019, p. 37). My identity as an a/r/tographer was especially central to organizing my research role in Cases 1 and 3. I took an a/r/tographic position through tailoring the cases and through the explorative data generation. A/r/tography was also of importance in Case 2, but this was discussed in the article *per se*. Developing an understanding of my own and others' sensory experiences has been central in my study; however, I did not consciously relate to *sensory ethnography* until Case 3. Pink (2015, p. 3) states that "sensorality is fundamental to how we learn about, understand and represent other people's lives and is increasingly central to academic and applied practice." Sensory ethnography is an embodied form of ethnography that does not supersede visual ethnography (Pink, 2013) but involves another layer and aims to move beyond the text and the visual to the senses, the non-verbal, and experiential knowledge (Pink, 2015, p. 160). Visual methods in this tradition are seen as particularly suitable for developing an understanding of touch and tactile ways of knowing (Pink, 2015, p. 168), and were partly the reason why I chose to work with sensory ethnography. As in a/r/tography, it involves participation and is an experiential process rather than an observing one (p. 75). It is a process of developing and representing knowledge that is based on my own experience. To develop an understanding of others' sensory experiences, I have to be aware of my own senses.

During this study, I used different *visual methods*. Holm et al. (2019, p. 313) describe how v*isual research methods* can contribute to creating other forms of knowledge than the verbal can do alone. In addition, Clark (2014, pp. 200–203) discusses how digital technologies can be included in research as part of a method to move beyond the spoken word to develop an understanding of children's experiences. In Cases 1 and 3, I took *photos* of instances and moments that I, as an a/r/tographers, found interesting during explorative interactions with students and children. In Case 3, the children also took photos during our joint explorations. In Case 2, I used photography as a part of my process of developing an understanding of virtual materiality and virtual environments. "Participatory photography" is often used as a tool to include researcher's photos, in addition to being a common way to engage children in research (Clark, 2014, pp. 200–203; Holm et al., 2019, pp. 316–317). Photos can be understood to be images of the body behind the camera because photos "refer back to the photographer at the moment of their creation" (MacDougall, 2005, p. 3). In this way, photos can contribute important sensory information for me as researcher.

In Cases 2 and 3, I used *video documentation* as a supplement to my own observation. I wore a headband camera during the explorations; I also placed an overview camera in one corner of the room. The camera attached to my body captured video close to my sensory experience and provided me with important sensory information such as speed and movement (Harwood & Collier, 2019, p. 54). My memories and sensory experiences from being in the context were important in the process of constructing data of the audio-visual material. Video became data through my processing of the video. Frederick Erickson, a professor in anthropology (2006, pp. 177–178), states that "video is not data" but "a resource for data construction, an information source containing potential data out of which actual data must be defined and searched for." The core of making sense of a visual experience lies in its sensory qualities (Rose, 2016, p. 34). Sensory ethnography is informed by an understanding that our senses are interconnected (Pink, 2015, p. 123). As described in the theory chapter (see 2.4), the visual can facilitate the experience of other sensory impressions and create illusions of, for example, tactile and haptic experience (Pusch & Lécuyer, 2011, p. 57). Haptic visuality has been an important part of my process of analyzing audio-visual documentation.

In Cases 2 and 3, I made *photo collages* as part of the data analysis and as a part of presenting my understanding of sensory experiences. The artistic technique of making collages is new within ABR (Scotti et al., 2019, p. 355). I have used the software program Procreate to create digital collages by using visual material from the cases. Collages can evoke, give access to, or foster sensory experience and embodied knowledge both for the researcher in the making process and for the viewer of the collage (Scotti et al., 2019, pp. 359–361).

In all three cases, I worked with *thick descriptions* as part of data analysis and as part of data presentation. Thick descriptions are short moments of interaction described in detail using poetic language (Stake, 2010). When I write that I use poetic language, I mean that I use the language to express my subjective experience of selected instances. I aim to use the language to express specifically my haptic and emotional experience, which I sensed in the situation. Eisner (2017, p. 15) describes "thick descriptions is an effort aimed at interpretation, at getting below the surface to that most enigmatic aspect of the human condition: the construction of meaning." The visual and the written text in this study aim to complement and enhance one another. As Irwin and Cosson (2004, p. 31) describe it, the visual and written text "do not duplicate one another but rather teach something different yet similar, allowing us to inquire more deeply into our practice."

During this study, I have also used *retrospective reflections* to help me interpret, understand, and learn from the explorative and creative process involving teacher students and children and from methodological choices and experiences based on different empirical studies.

4.1.5 The Question of Validity and Applicability

ABR is, in many ways, the opposite of the scientific methods where hypotheses are tested and findings are considered to be generalizable (McNiff, 2019, p. 32). Traditional discipline-based and standardized methods with criteria such as validity, objectivity, and generalizability are being developed and adjusted to study human experience (McNiff, 2019, p. 32). An example of this is how personal and subjective emotions previously were not seen as valid informants (Groth, 2017, p. 66). Important concepts in qualitative studies like ABR are "trustworthiness" and credibility. The aim of qualitative findings is not their generalizability; rather, it is to make a meaningful contribution to human experience (Stake, 2010, pp. 56–58). Even if we cannot apply the findings directly, they can be useful and relevant in related situations. Qualitative research "makes a contribution to the assessment of value with the idea of examining 'trustworthiness,' rather than the scientific measure of validity" (McNiff, 2019, p. 33). One way to establish trustworthiness is through transparency (Stake, 2010, p. 15). I strive to be honest and aim to establish it through describing all the steps in the research process as clearly as possible. These aspects are central to being trustworthy in qualitative research (Skærbæk, 2007, p. 73). Stake (2010, p. 123) also describes how qualitative researchers' triangulation of findings is a form of confirmation and validation of research. In my study, I used different methods as in Case 2, where I generated four types of data using methods such as diary questions, think-aloud accounts, and video documentation. This was a way to capture my ongoing reflections and interpretations as they happened, as well as afterwards. In Cases 1 and 2, I collaborated with other researchers who also co-authored the publications; thus, data generation and analysis have not taken place in a vacuum. I have also actively participated in national and international research environments, and my research has been regularly shared and discussed.

I have strived to both work systematically and to be open to using my senses and different ABR approaches. What characterizes a making process is that one does not know what the outcome will be in the beginning and which tools are needed in the processes. In fact, I was not always aware of which tools I would be using in the different cases, even though they were carefully planned and implemented. An example of this is Case 2 were I used photography a means to develop understanding of virtual materiality and virtual environments. I did this as a

natural part of my artistic practice; however, it was not until after the study was published that I understood that this was an important part of my developing of understanding.

4.2 Overview of the Cases and Research Setting

In the next section, I present the three cases, data collection, and generation of this study. What follows is a short description of the cases and a summary of the participants, data, and the focus and method of analysis of each case (Table 4).

In *Case 1*, we conducted a three-day teaching project with students in ECTE at USN. The students were invited to explore and experiment in an arranged project room with different materials and technologies together with me and two co-researchers, Ann-Hege Lorvik Waterhouse and Kari Carlsen. Their research interests are arts and crafts in ECE. The study explored the student's experiences and expressions with combining different materialities. Through the exploration, interaction, and observation, we positioned ourselves as a/r/tographers. The empirical material was made available and presented as thick descriptions (Stake, 2010). For Publication I, we framed the analysis and discussion around four instances of explorative interactions. In *Case 2*, I interacted with and explored a picturebook app produced by Wuwu & Co. The aim was to develop understanding about sense-making through explorative touch interaction with the app. The app was studied through an in-depth explorative inquiry supported by diary questions and audio-visual documentation. The publication was written together with a co-researcher, Professor Marte S. Gulliksen from USN. The analysis was conducted in two parts, first through selecting three scenes from the app for closer analysis. Then, one scene was selected for further exploration and analysis and developed into a thick description (Stake, 2010). For Publication II, we framed the analysis around three selected scenes and the discussion around one selected scene.

In *Case 3*, I involved six children, ages 5–6, in explorative touch interactions with different materials and digital technologies in a facilitated project room at USN. The study explored the children's experiences and expressions with combining different materialities. The children's interactions were studied through explorative inquiry supported by audio-visual footage. I took a participating explorative observation role positioned as a/r/tographer through the data generation. I also took photos of important events through the exploration. All the audio-visual footage was transcribed, including facial expressions, gestures, movements, and verbal utterances. Five material instances were chosen for closer analysis. Thick descriptions

were developed from three of these instances. For Publication III, I framed the analysis around three selected instances. For the last article, I did a new analysis based on the data from Cases 2 and 3. The focus was to develop an insight into my own methodological choices and methods used in Cases 2 and 3 to gain insights into my own and the children's movements in physical and virtual environments. For Publication IV, I framed the analysis and discussion around two themes.

Table 4. Summary of the participants, data, and focus and method of analysis of each case.

Case	Number of participants	Data	Focus of analysis	Method of analysis
1	20 students	Observations Students documented process, photos, and reflections The a/r/tographers' retrospective reflections Photos Notes	Experimental and the unforeseen in exploring materialities	Qualitative content analysis Developing of thick descriptions
2	1 researcher (me)	4 h audio-visual footage Think aloud accounts Exploration of the picturebook app Photos Notes	Touch interaction Embodied experience, exploration, and sense-making	Video analysis Transcriptions A detailed view analysis of three selected scenes An in-depth analysis of one scene Developing of thick descriptions Making photo collages
3	6 children 1 ECE teacher	5 h 50 min audio-visual footage 100 photos by me 500 photos by the children 20 short videos by the children Notes	Touch interaction Embodied experience, exploration, and sense-making	Video analysis Transcriptions A detailed view analysis of three selected instances Developing of thick description Making photo collages
2 and 3	6 children 1 ECE teacher 1 researcher (me)	Data from Cases 2 and 3	Methodological choices and methods Embodied experience and sense-making	Qualitative content analysis Retrospective reflection

4.3 Case Description and Data Generation

In the following section, I describe the three cases and present the methods used for data generation and analysis.

4.3.1 Case 1: A Group of ECE Students and Three A/r/tographers' Explorations of Materialities

The case was set within the course: Material and Digital Exploration in Children's Arts and Crafts Processes (in Norwegian: *Material og digital utforsking i små barns formingsprosesser*) offered by the Department of Visual and Performing Arts Education. Each year, a group of about 25 bachelor's degree students participates in this specialization course in ECTE at USN. I am one of the teachers of this course. The aim of the course is to provide a specialization in educational arts and crafts processes with different materials, techniques, tools, and digital technologies. The focus of the course is to provide students a setting in which to develop a deeper understanding of children's play and creative activities in ECE, and expand their preconditions to stimulate children's material and digital forms of expression in the learning process. The course focuses on phenomena that arise in processes where materials, digital technologies, and a variety of expressions are in mutual exchange with nature, culture, and art.

Twenty students participated in a three-day teaching project called Material and Digital Landscapes during the spring of 2017 (Figures 6 and 7). The students were invited to a large-scale project room at the university, which we a/r/tographers had arranged as an invitation for exploration. Available in the project room were different types of materials such as natural materials and plastic. In addition, iPads, flashlights, and projectors were available in the room. Material and digital landscapes refer to what can occur in a space when different materialities are combined and infused in experiences and artistic expressions. The students did not get an explanation or an assigned task prior to the teaching project. It was presented as an open invitation to explore opportunities and expressions with the materials and technologies available in the room. The students were encouraged to explore collectively and pay attention to the a/r/tographers and each other's explorations. The students were encouraged to take photos and video, using their smartphones and iPads, of the visual expressions generated from our joint explorations. The second day, they received a task asking them to make an artistic video during the project. This educational arts and crafts context, we believed, would be a good context for addressing the research question.

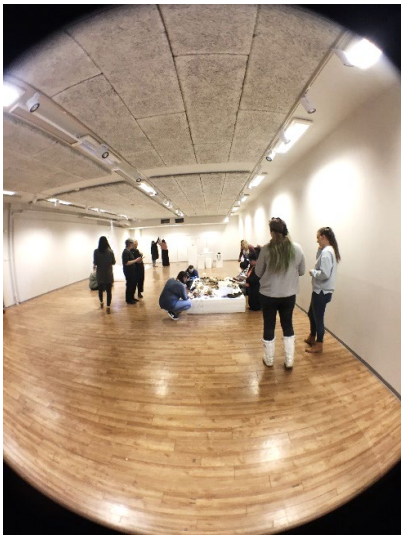


Figure 6. The ECE students' (ages 20–50) first exploration in the project room. Photo by Lovise Søyland.

Figure 7. Two ECE teachers' exploration of the mediated materiality through their mobile phones. Photo by Lovise Søyland.

The main method used for data generation was participatory observation and collective explorations together with the students in the educational setting. Ahead of the teaching project, we, the teachers of this course (Ann-Hege Lorvik Waterhouse, Kari Carlsen, and I) informed the students that it was voluntary for them to participate in the research study, and the students filled in an informed consent ahead of the implementation (see the research ethic section for more information). In teaching and guidance, we were positioned as a/r/tographers. Through the living inquiry into the interactions with students, materials, and technologies, our attentive and personal experience was of importance. Doing a study like this requires being in a constant changing process: "a/r/tographers are living their practices, representing their understandings, and questioning their positions as they integrate knowing, doing, and making through aesthetic experiences that convey meaning rather than facts" (Irwin & Cosson, 2004, p. 31). During participatory observation, we studied the student's bodily and facial expressions and verbal utterances when they made discoveries and when they were immersed in the process. We also studied their personal and collective artistic expressions in the room.

Different types of data were generated. The main method was observations through explorative participation, from the position of being a/r/tographers. We reflected and discussed our observations through and after the exploration, which relates to Schön's (1983) term reflection-in- and on-action. In addition, we recorded notes about the activities. During the exploration, we also photographed our joint interactions and the different expressions that occurred in the "landscapes." In two of the instances of exploration, which we chose to present

in the article, we included the students' own documentations, descriptions, reflections, and photos in the empirical material.

During the analyses and the writing process, we three a/r/tographers had several meetings discussing the instances and empirical data. We started to develop thick descriptions (Stake, 2010) using a poetic language of the relevant instances that shed light on the research question. We also started to write collaboratively in one document. In this way, we could write simultaneously while also continuing our meetings to discuss the content of the article. In the analysis, we identified four main themes, which highlighted important aspects of the exploration (Table 5). The main themes were followed up by a discussion of five themes in the article (see Table 5).

Table 5. Themes of the thick descriptions and analyses.

Four main themes were the foundation for the thick descriptions	(1) Cod skeleton and macro lens magic and exploration of a dried leek flower and light refraction (2) The unforeseen (3) The art of choosing and pursuing discoveries (4) Discoveries and expressions processed and transformed into video
Five main themes formed the starting point for the discussion.	(1) Retrospective reflections (2) The experimental and unforeseen in collectively creative rhizomatic processes (3) Technologies and tools (4) Materials in flow: from matter to transmateriality (5) Toward a new creative and digital practice in ECE

4.3.2 Case 2: Exploration of My Own Touch Interaction with a Picturebook App

In this case, the picturebook app Wuwu & Co. – a magical picture book (Helle & Slocinska, 2014) – a virtual reality story was selected for addressing the research question. The app was examined through my own explorative touch interaction. The fictional world in the app is beautifully illustrated and completed with an integrated soundscape, a narrator, and a text. When the device is horizontal, the app resembles a book (third-person perspective). When it is held upright, it becomes a window into the world (first-person perspective); see Figures 8–10 for illustrations from the Wuwu & Co. app. The narrative is played out in five different scenes. The titles of the scenes are *Everett and The Secret Place*, *Thit Maya and The Pinecone Tree*, *Wuwu and the Shark*, *Pruney, The Troll of Little Mountain*, and *Storm and Snow Lantern Field*. There is one scene for each character in the story, which is integrated with innovative use of

interaction. Especially the innovative technological features of interactivity, such as touch and virtual reality, made the app relevant to our study. In addition to the app's other qualities are the genuine, beautiful, and playful expressions in the illustrations, which, I think, are important for the children encounter.

The generation of data through explorative inquiry (Dyrrsen, 2010) was planned and conducted by me. Ahead of the exploration of the app, I had to do preparations and make choices. First, I had to choose where to conduct the study. I considered what kind of room I would need and what I would need available in the physical space. I chose a room at the university that was big enough so I could move around easily. I also had to find a room at my university where I could conduct the study in quiet surroundings, without being disturbed. I also had to plan for setting up a video camera and how to document my interaction with the app.

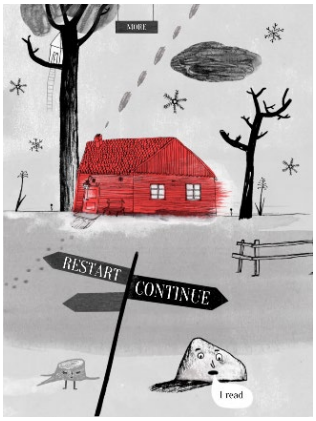


Figure 8. The start-up side.

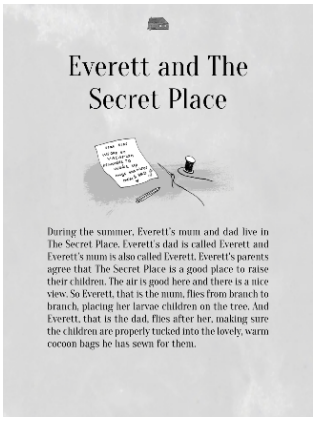


Figure 9. The "book-side" and written story about Everett.

Figure 10. Everett outside the house in front of The Secret Place. Illustrations from the Wuwu & Co. app © Step In Books, 2014.

In explorative inquiry (Dyrrsen, 2010), a researcher explores and interacts with the object of study, and targets his/her inquiry through explorative actions. This approach enables the researcher to generate rich and complex data, that otherwise can be difficult to grasp (Dyrssen, 2010 p. 230). As such, this method provides data on different types of expressions in human actions, which can be used to infer knowledge of the sense-making process during the exploration. An integral part of documenting such an explorative inquiry is to capture the ongoing reflection and interpretation as it happens and the reflection afterwards (Schön 1983).

The story line in the app was completed twice by me, from beginning to end. Following the story line means to follow the narrative which, in this app, is played out in five different

scenes, with five different characters (see the descriptions above). I followed the story line in two different rooms. The first time I did this in a classroom with furniture, and the second in an empty exhibition room. The decision of changing rooms was made after the first completion of the story line because found that I needed more space to move while interacting with the app. I had not foreseen how much I was going to move around in the physical room, while interacting with the virtual. Thus, I then understood that I needed more space to move while completing the story line. Marte Sørebø Gulliksen, author two, also completed the story line, but did not participate in the explorative data generation. Immediately after the analysis, the tentative main findings were narrowed down and explored through discussions between us. We then both contributed equally to writing the article.

Four types of data were generated:

1) *Pre-exploration diary questions* were answered verbally. In this study, I was especially inspired by Groth's (2017, p. 45) way of using this method. Diary questions are an established way of collecting autoethnographical data (Bolger et al., 2003). See Table 6 for the diary questions in this study. Answering the diary questions was a way to prepare for the exploration and capture my reflections and emotions before the exploration, a way of collecting autoethnographical reflections. The pre-exploration was also important to understand how the exploration affected me and how I, for example, changed emotionally from before to after the exploration. Video footage also gave me the opportunity to study my facial and bodily expressions while I answered the diary questions.
2) *Exploration* of the app, while I followed the story line twice. I made verbal think-aloud accounts, also inspired by Groth's study (2017, p. 44), of my experiences and interactions. No exploration guide was used. I documented this with two video cameras: one headband camera capturing where I looked, how I moved, etc., and one overview camera capturing my expressions and my movements in the room. Both cameras also captured audio.
3) *Post-exploration diary questions* were answered verbally to capture my immediate experiential reflections (see Table 6). Also, in the post-exploration diary questions, video footage was helpful in studying my own different expressions while answering the diary questions.

4) *Data generated after the analysis: Thick descriptions* of selected instances (Stake 2010) were developed. Through imaginings, thoughts, movements, and associations from the think-aloud accounts in action and from the verbal responses to the diary questions including facial and bodily expressions, these descriptions were unpacked. Drawing on ABR methodology (Barone & Eisner, 2012), a poetic language was used to develop these thick descriptions.

Table 6. Diary questions.

Pre-exploration diary questions	*Post-exploration diary questions*
What are you going to do and how?	Did you manage to do what you intended?
What are the challenges involved with what you are going to do?	Did your plans change? Why? How did you react?
What are you thinking right now?	What were the critical points?
How do you feel right now?	What facilitated or hindered you in your process?
	How do you feel now?

The total amount of video/audio footage of exploration and diary questions was four hours. Raw data of thick descriptions was approximately 5,000 words. All audio-visual footage was transcribed, including facial and bodily expressions, gestures, verbal utterances, and movements, in particular, movements that included touch. The focus when transcribing was to capture the rich and complex experience through the bodily and verbal expressions in both the exploration and the diary questions. In exploration, this was done, for example, when the device was lifted over the head in interaction with virtual snow. In the diary questions, for example, interaction with the virtual forest memories of touching snow was significant in the experience; this was expressed verbally and through facial expressions. The bodily expressions were especially important when I struggled to express myself verbally.

The analysis of the data to the point of achieving tentative main findings had three phases: first overview, detail view, second overview.

1) *First overview analysis* started during the transcription phase and continued afterwards, reviewing the video and reviewing the transcriptions, and searching for instances where the interaction between me and the story line were particularly intense. These instances were found through studying my interactions and expressions, for example, when there was much activity or movement, or when I was surprised over my own reaction. Because I studied my own exploration with the app, I could use insider-knowledge to understand what happened in the audio-visual footage, and this insight was used to identify important instances of interaction. Three scenes: *Wuwu*

and the Shark, *Pruney*, *The Troll of Little Mountain*, and *Storm and Snow Lantern Field*, stood out, and were selected for closer analysis.

2) *Detail view analysis* focused on three scenes involving the characters Wuwu, Pruney, and Storm. These scenes were found especially relevant for developing an understanding of how touch interaction with the picturebook app could facilitate or limiting sense-making. Thick descriptions of all three scenes were developed as written drafts, generated based on reflection-in-action (in-action captured on video footage and in-action when reviewing the video data), and reflection-on-action (Schön 1983). As such, this process was both part of the data generation (see above) and part of the data analysis. Through this drafting process, the one scene with the character Storm, showed most potential for further exploration and analysis, based on how strongly the scene evoked my memory, the scene's opportunity for touch interaction, and the intensity of my experiences. This scene was developed into a finished thick description. Thick descriptions were used to explore the experience, movements, and associations from the explorative touch interaction.
3) Lastly, the *second overview analysis* aimed to revisit the entirety of the material, in order to give an overview of instances of interaction and experience. A table was developed to give structure to this analysis in the form of five columns: Scene/name, Character involved, Possible forms of interaction that have been programmed, Effect of interaction for the story line, and Researcher's experience with interaction.

The analysis concluded with identifying four main themes that each highlighted important aspects of the app's facilitation or limitation of touch interaction: 1) material and materiality, 2) empathy and imagination, 3) interaction and relationships, and 4) boundaries for interaction. These themes are discussed in the Analysis and Discussion sections in the article and are further articulated in the discussion of this dissertation.

Early in the process of analyzing the data, I took several walks in the snowy Norwegian forests. During my walks, I paid attention to my own embodied movement in this physical landscape and the properties of snow. I was attentive to the slippery and snowy surface under my feet and the visual impression the snowy landscape gave me. I had my mobile phone with me, and I photographed my surroundings. I processed these experiences, which I think was largely set in motion by my feeling of being immersed in the virtual landscape in the app. I used the app Procreate for artistic processing. I worked with cutting photos, adding colors, etc., and I also made digital collages to express my experience. This processing also became a part of

my understanding of my sense-making during interaction with the app. However, I did not included this as part of my empirical data (see also section 4.1.5).

Explorative inquiry (Dyrrsen, 2010), operationalized in this way, gave me the opportunity to explore the events from an insider perspective and discuss this exploration with author two, Marte S. Gulliksen. This co-authorship approach afforded opportunities to identify and mediate possible bias. My experience of the interaction with the app was close to me and emotionally felt, and this subjective experience was central to deepening the understanding of how sense-making was limited and facilitated by this app. The co-authorship and the gaze from a researcher, who had not been involved in my experience, was helpful in making the empirical material accessible and relevant to others. Additionally, the research design was discussed with experts before and during the data generation.

4.3.3 Case 3: A Group of Children, Their ECE Teacher and My A/r/tographic Explorations of Materialities

To address the research question, I invited six children ages 5–6 and their ECE teacher to participate in the study. Their ECE had just started to use touch devices and other digital technologies in the pedagogical work with the children. The teacher and the children were to some extent familiar with digital technologies. The aim of the study was to investigate the children's sense-making through their interactions with different materialities. The children were divided into two groups of three. On day one, I met the two groups separately in their kindergarten to get to know them. On days two and three, the two groups of children were invited into a large-scale project room at the university, which I had preorganized for exploration (Figures 11 and 12).

I arranged the room to invite the children to engage in explorative interactions with different digital technologies – such as iPads, projectors, macro lenses, and flashlights – and physical materials – including leaves, a thorny twig, and a buck skull. This was a part of my process of tailoring the case to get to the core of what I wanted to study (Stake, 2010, pp. 83–86). I used my past experience of the materials and digital technologies' properties and affordances to facilitate the room in a way that I imagined would be exciting and challenging for the children. I considered how the different materials through interaction and manipulation make different sounds, what the surface and the weight of a material feels like through tactile and haptic perception, and the possibilities in combining different materials and technologies in exploration. I also chose materials which had variable tactile properties, such as sharp,

smooth, soft, and rough, and materials with surfaces that had different resistances. I chose both natural materials and human-made materials like plastic. I also made choices about how I would present and arrange the materials to invite them to participate. Prior to conducting the case, I reflected upon what could arise during the exploration that needed ethical considerations. I also discussed ethical challenges with other more experienced researchers. This is described in the ethical section.

Figure 11. Photo of some of the available materials in the project room. Photo by Lovise Søyland.

Figure 12. Three of the children interacting in the project room. Photo by Lovise Søyland.

Since the children and their ECE teacher were invited to the university, the study was not a real-life study in ECE, but it was still important to relate to the children's everyday lives and routines. There were several conditions that constituted the structural framework for the research context. An example of this is how I related to the ECE structure by starting our exploration at 10:00 a.m. and continuing as long as the children wanted, including during lunch, and then continuing afterwards for about 20 minutes. I made clarifications with the ECE teacher about the organization of the days and her explorative role in the project room together with the children and me. Research choices are necessarily determined by ethical considerations, so they are designed according to what data is possible to be collected ethically. Thus, I made sure that the children were familiar with me, and that we were together with their ECE teacher inside a closed room. I also took responsibility for ethical considerations regarding audio-visual documentation; see also section 4.4 about research ethics.

The generation of data was conducted over three days. The exploration with each group on days two and three lasted for approximately two hours, including a break. Through the study, I was positioned as an a/r/tographer (Irwin et. al., 2019) and sensory ethnographer (Pink, 2015). Together with the children and their ECE teacher, I took an active part in the exploration. I was prepared to be explorative and present, and I was attentive to the children's actions and

potentials to make new experiences and artistic expressions. One headband camera (on me), and one overview camera of the room documented the exploration. In addition, I took photos of important instances with a camera. The children also took photos and videos by themselves. Through the participatory explorations, I could also study different kinds of expressions of the children (words, facial expressions, bodily movement, sounds, etc.). The observations were written down the same day, immediately after the exploration was conducted. Video footage was used as a supplement to observations and notes. The total amount of the empirical material was six hours of video footage, 89 photos taken by me, and 500 photos and 20 short videos taken by the children.

All audio-visual footage was transcribed including facial and bodily expressions as in Case 2. The focus was to capture the rich and complex in the children's experiences. I transcribed the spoken accounts and supplemented these with my own written observations of the other aspects, such as gestures and movements.

The analysis of the data to the point of tentative main findings had four phases:

1) A first overview analysis was made during the transcription. The raw data included transcribed video, screen shots from video, and series of photos taken by me and the children as well as observational notes, which were combined in a document that comprised 70 pages. This empirical data was first arranged chronologically. The focus of the analysis was the children's sense-making which was interpreted through their expressions in their explorative interactions. An example of this could be sounds of amazement or facial expressions that could be understood as being surprised or the result of making a discovery. Through the first analysis, a number of themes and issues emerged in different instances such as explorative interacting with physical and virtual materialities.
2) I focused on five material instances: leaves, a thorny twig, a buck skull, a piece of wood, and a purloin flower. The selection criteria were based on my understanding of children's sense-making and explorative interactions. I studied what the children touched and how they did this, that is, in what way they touched and tried to find out how their touch led to sense-making. I studied audio-visual clips in depth. I also used audio-visual clips to recall my memories and feelings about what occurred in single moments when I understood that the children made discoveries. Through this process, the data were narrowed down to a document comprising 40 pages.

3) In this phase I assembled the material instances under four different themes: sense-making and emotions, material (including digital technologies as material objects), tactile and haptic perception, and materialities. I analyzed the data with the main focus on, for example, emotions in one review and touch in another review. In this phase, I switched focus by returning to phases 1 and 2 and observing the audio-visual and photographic material.
4) In the last phase, I focused on three instances which stood out as being relevant to answering the research question. These were: (1) leaves, (2) a thorny twig, and (3) a buck skull and a virtual iPad button. The instances were not just related to a single moment, but to the sum of the instance during the two hours the children were in the project room. I developed thick descriptions of these instances (Stake, 2010) using a poetic language in the same way as in Case 2. The thick descriptions were supported and completed by photo collages which I made with photos taken by the children and me and stills captured from the audio-visual footage. The analysis was concluded by identifying three main themes: (1) materiality, movement, and touching with light, (2) virtual materiality and touch, and (3) materiality, exploration, and experience. The first theme was based on the instance with leaves, the second theme on the instances with the thorny twig and the buck skull, and the third and second theme with the instance of the buck skull.

4.4 Research Ethics

Research ethics is about behaving ethically, making good choices, and respecting formal laws and guidelines through all the stages of a research process (NESH, 2016, p. 5; Skærbæk, 2007; Tangen, 2013). As researcher, I am always in a constant dialogue and process with ethical implications, striving for knowing my own attitudes and prejudices (Stake, 2010, p. 15). This is complex because ethics is both culture- and context-dependent. It is about treating the involved children and adults with integrity, dignity, respect, and confidentiality through the planning, implementation, and analysis and in sharing and presentation of research. Ethical considerations have influenced all the stages through my research process. In research ethics, context transparency is a primary goal, and researchers must make their choices visible to others. My research ethics has been influenced by my past experiences and values in relation

to ontological and epistemological positioning. The NESH (2016, p. 5) describes research ethics in this way:

> It refers to a wide variety of values, norms, and institutional arrangements that help constitute and regulate scientific activities. Research ethics is a codification of scientific morality in practice. Guidelines for research ethics specify the basic norms and values of the research community. They are based on general ethics of science, just as general ethics is based on the morality of society at large.

Research involving examination of ECE students and especially young children involves many ethical considerations. In Case 1, it was voluntary for the students to be involved. All the students' filled out an informed consent which gave me permission to use observations and photographs in the research project. The students were assured that they would be anonymized. Whether their participation was voluntarily can be questioned because they were asked to participate in a study as a part of their educational arts and crafts project at the university. This may have exerted pressure on them and created a feeling of not having another choice. This can be seen at problematics in relation to the idea that "freely given consent means that the consent has been obtained without external pressure or constrains on individual freedom" (NESH, 2016, p. 15). In Case 2, I studied my own interaction, and the research setting allowed all data to be generated on and by me. In Case 3, young children and their ECE teacher were involved. Early in 2018, I established contact with a local kindergarten. After I got feedback from the kindergarten that they would participate in the study, I contacted the Norwegian Centre for Research Data (NSD), and they approved the study. This is a requirement, but also an aid in adhering to the privacy act and formal ethical privacy guidelines. A formal written invitation, including a consent form for participation, was given to the parents and the ECE teacher. The consent was sent to parents of a group of 10 children aged five and six, and it stated that I would be permitted to take photos and video recording of the children. Six parents responded positively. In Norwegian ECE, procedures for collecting personal information such as photos of children are well established. Parents for children under 16 years of age can give consent for their children to be involved in research.

In the following, I will focus on ethics in the context of involving children in Case 3. Involving children in research requires going further than showing that rules of research ethics are followed. Children's consensus is complex, and they are vulnerable in this context (NESH, 2016, p. 20). One reason for this is that children cannot formally refuse to participate in

research. They are also more willing to obey authority than adults are, and children can often feel that they cannot object (p. 21). An important point in this context is that the researcher must have enough insight about children "to be able to adapt both their methods and the direction of their research to the ages of the participants" (p. 20). It was especially important for me to get to know them and try to make them aware that the exploration was going to be recorded. I talked with the children about their involvement being voluntary and that they could withdraw from the activities at any time. Thus, I was attentive to their body language in relation to their involvement during the implementation of the study.

Selection of materials and digital technologies presented both pedagogical and ethical challenges. The choice of materials was about choosing materials that could not be dangerous for the children. I also had to consider how to present, for example, materials such as glass and a piece of cloth hanging from the roof. The selection of materials also had ethical challenges in relation to showing value and respect for nature and the environment by making natural materials available. In selecting and presenting materials, I used my knowledge of the materials' properties and affordances, and these choices were significant for how the exploration could unfold. I also had to address ethical considerations in relation to which digital technologies I would include in the study and which software applications would be used. I deleted apps that the children should not use on the iPads and made sure that the iPads were empty of pictures.

My aim was to create a safe and comfortable atmosphere for the children. I talked with the children, telling them that I was genuinely interested in learning from them. My impression was that this made them proud. They felt included and understood that their opinions were valuable for me. This is also pointed out by the NESH (2016, p. 21) as they recommend that children at this age involved in research must be provided with the opportunity to express their opinions.

The nature of children's exploration and play and their routines from their ECE were taken into account. I also talked with their ECE teacher prior to the exploration and clarified what to do if the children, for example, got tired and hungry. Defining roles and responsibilities with the ECE teacher was important to secure the children's well-being (see also NESH, 2016, p. 23). The goal was to build trust with the children. The size of the groups of three made it possible for me to give all the children my attention and come close to them during interactions. It was also essential to observe their joint interaction, so it was not an option to be alone with only one child. This was important both for ethical considerations and for the benefit of the quality of the study. To connect with them and gain access to understanding their experience, I was dependent on being trusted by them.

The first day, I spent time with the two groups, one at a time, inside a closed room in the ECE. This situation required ethical considerations. It was the children's choice to stay with me. The children were in a familiar and safe environment in their own ECE, with adults well-known to them outside the room. The children were also familiar with each other. I was constantly aware of the children's body language and paid attention to their well-being. On days two and three, our interactions took place inside a large-scale project room at the university. The closed rooms were necessary because of the video recording and because I needed to be close up and attentive to the three children. Young children may have difficulty understanding when they are being videoed. In the process getting to know them, I let the children make videos and take photos with the headband-, video-, and SLR-camera that I was going to use for documentation. This was part of the process of honoring my ethical responsibilities to the children and making them aware of me taking photos and audio-visual recordings. All video and photo data were transferred to an external hard drive.

After the exploration, I had to handle the video and photo material and take into consideration what could be interpreted as confidential, private, or concerning information – such as children's close up pictures of each other making grimaces. I made decisions about what to do with material of this type, and some of the children's photos I decided to delete the same day. I looked for video material that could affect their safety or well-being. To protect the participant's anonymity and privacy, the external hard drive and field notes were stored in a secured area. I made it known that the data would not be stored longer than necessary for the purposes of the study. To ensure the anonymizing, I also cropped and blurred photos in the publications. In the following section, I will present the main findings of the study.

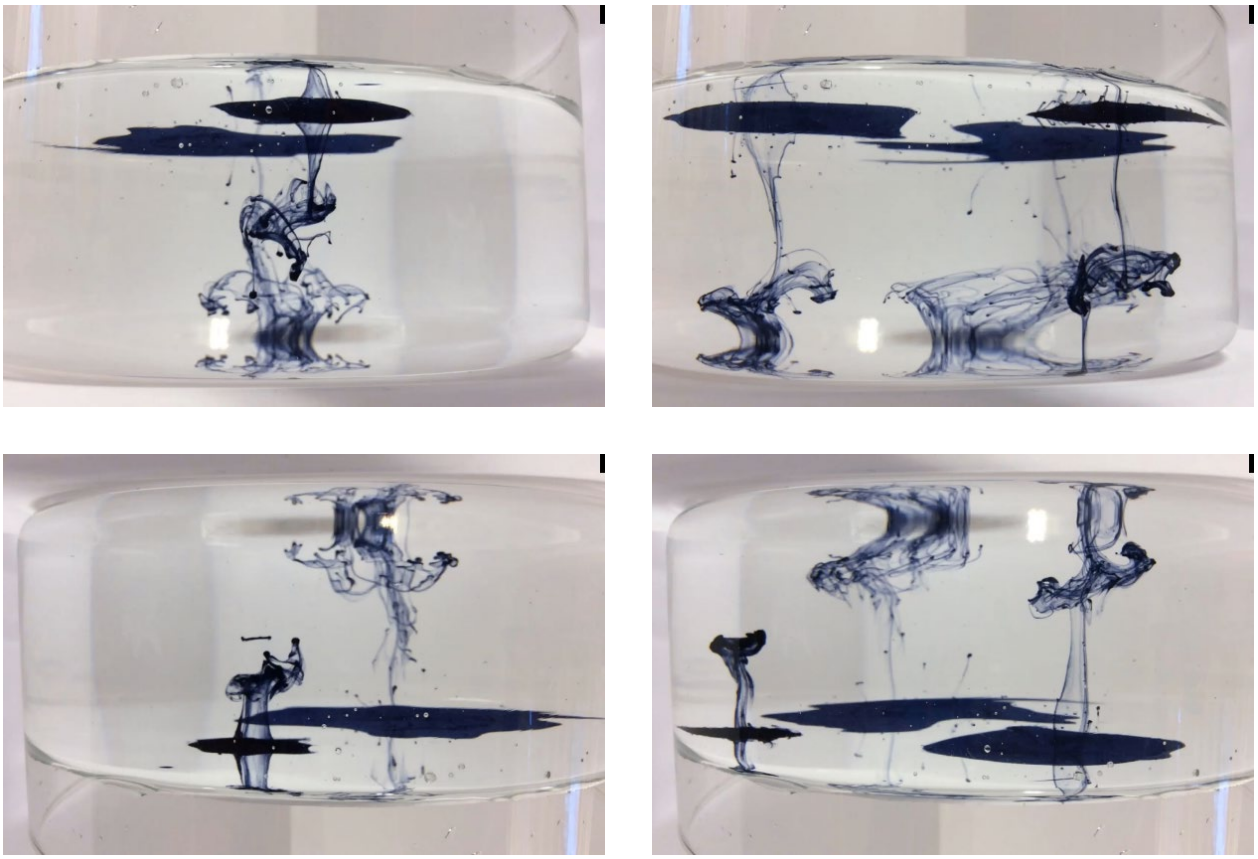
5 Main Findings of the Study

5.1 Experimental Explorations of Materials and Materiality in Transmaterial Landscapes (*Publication I*)

Publication I was written as a result of Case 1 and answered the sub-question: *What happens when we open up to experimental and unforeseen processes that transform physical and digital materials and phenomena into creative processes?* The publication discusses how a group of ECTE students in an arts and crafts educational project together with three a/r/tographers (the authors) explored materials and materiality in transmaterial landscapes.

One of the findings from the study was how discoveries and new expressions took place in collective creative processes that branched out in different directions like a rhizome. A concrete example of this was one of the student's explorations of colors and water while videoing. The student dripped drops of different textile colors into a glass bowl filled with water. She experienced a spiral motion of colors dissolving in the water in that moment and captured it on video. A fascinating artistic expression occurred as the water turned murky. The murky water gave the student resistance. The student was encouraged to do it over again, using only one color. In a joint exploration with the student and us a/r/tographers, new discoveries were being pursued. The process could be described as a way of eliciting, being aware of, and using the senses while searching for artistic qualities and fine-tuning the expression. Video of the materials infusing in slow motion gave the expression poetic qualities. The student expanded this expression by editing the video, thus working with rhythm, movement, speed, and sound. In the end, the student gave her video the title: "Dancing Drops" (Figures 13–16). Some students initiated other explorations with water, such as projecting moving water into the room.

Another result from the study indicates that the setting provided opportunities for transmateriality to emerge by using the student's own bodies, senses, materials, and digital technologies. The unforeseen has a key role in this process. An example of this is when plastic/cellophane accidentally melted on a lamp. The texture of the melted plastic was captured in a photo and projected onto the surface of the room (the walls, ceiling and floor) and became a new unforeseen artistic expression.



Figures 13–16. Student work. Stills from the video "Dancing Drops." The student pursued discoveries making poetic expressions.

Through the study, I identified how a macro lens attached to a touch device was in close relationship with the student's body and emotions during exploration. The student explored a dried leek flower close up using a macro lens. Her process was identified as a *haptic search* for new expressions. During the exploration, she reached out to feel the texture of the dried leek flower. The student was excited and fascinated by the experience of the change in the materiality and described how she "fell in love" with the macro lens. Her photos were projected onto the surface of the room. It was a process that created new expressions layer by layer. Projections were being photographed as they were displayed in the room again. The use of digital technologies for exploring different materials and phenomena in working with spatial expressions was a way of expanding and multiplying the possibilities of space and digital technologies in artistic expressions and creative practices. The surface of a room can be used as a canvas for exploring transmaterialities. It was a way of expanding the sensory experience with different expressions and materialities. Through the study, it was especially noted how the creative learning processes and explorations in this setting incorporate bodily movement in exploring materialities (Figure 17).

Figure 17. A collage of a/r/tographers and students in intra-actions. Photos and collage by Lovise Søyland.

The teacher students used digital technologies in a process of exploring new aspects of materials. To discover possibilities and make opportunities, an open-minded and experimental approach to the phenomenon studied is needed by both students and teachers. Many students felt resistance in the creative process – it seemed like it was unfamiliar for them to work with open-ended processes and to not know what the outcome would be. However, these students were the previous year's bachelor's degree students and had worked with creative process during their two first years in ECTE. To work with non-linear processes required that they used their senses in relation to the dynamic of the phenomenon. It takes courage to let go of safe habits and enter into the unknown, exploring artistic expressions and taking the unforeseen into account.

5.2 Sense-making through Touch Interaction with a Picturebook App *(Publication II)*

Publication II was written as a result of Case 2 and answered the sub-question: *How is touch interaction with a picturebook app facilitating or limiting sense-making?* The publication discusses how sense-making is facilitated or limited through touch interaction with the picturebook app Wuwu & Co. These were discussed through four main themes: (1) material and materiality, (2) empathy and imagination, (3) interaction and relationships, and (4) boundaries for interaction.

Two potential core paradoxes, the paradox of materiality and the paradox of interactivity, concerning sense-making and a person's physical engagement with the touch device and software of the picturebook app were found. The study reveals that picturebook apps, unlike physical picturebooks, have the potential for interactivity that more easily can

evoke the previous physical experiences of materials, empathy, and emotions in the user. In interaction with the picturebook app, the two-dimensional screen only allows for small movements and tactile information from a smooth surface, which means that the reader must imagine, for example, the texture, heaviness, and size based on past experiences with materials. In this context, the haptic visuality has a central role because it bridges the gap between the material and the virtual.

Through the study, I developed an understanding of how I was immersed in a virtual space of a snowy forest through technological features. By experiencing virtual falling snow visible on the screen as I simultaneously moved my body in the physical room holding the device over my head and looking up into the virtual sky, my past experience of the tactile stimulation of physical snow was evoked. The features, the virtual materiality, and the movement evoked past experience of physical space and snows. This is defined as the *material paradox* of virtual realities (Stenslie, 2010, p. 128). In the study, tactile feeling of snow was induced through imaginations and implicit and declarative memories. The experience of being immersed also induced emotions in me and a feeling of empathy for the characters. The interaction with features, such as melancholic music, eye expressions, and the characters' movements, evoked emotions. The characters were not physically there, but the movement and virtual materiality gave me the feeling that they were present and that I connected with them in a way. The interaction gave me the feeling of being safe inside the virtual house together with the virtual characters.

The study indicates that interactivity in the picturebook app is limited, and that this influences the process of sense-making. The interactivity is limited to a predetermined number of possibilities to interact (determined by the app developers), especially the possibilities to influence the narrative through the features of the technology. An example of this is a task in the app which is to light a lantern to calm the characters who are afraid of the dark. It is not possible to make another decision like lighting a bonfire. The app is preprogrammed to tell a story and to evoke certain reactions and emotions. The interaction is similar to following someone else's path without the opportunity to create new solutions. The study identified that this is problematic given that sense-making is closely connected to the co-creation and creation of opportunities for imagination and action. The illusion of collaboration is more a requisition (co-opting) of certain actions.

These findings are useful for facilitating sense-making processes with digital technologies. It is valuable for a teacher to be aware of how important previous material experience is for children to make sense of similar picturebook apps and technologies. It is also

important for teachers to be aware of how these kinds of apps have limitations in facilitating sense-making and co-creation. Even though this app has limitations, it is groundbreaking as it provides more possibilities to be immersed in a virtual world than many other previous formats. These findings are significant for teachers in terms of how they can facilitate and use digital technology in learning contexts. I will come back to this in the discussion chapter.

5.3 Children's Sense-making through Exploration: Grasping Physical and Virtual Materialities *(Publication III)*

Publication III was written as a result of Case 3, and answered the sub-question: *How do young children make sense of the world through explorative touch interactions with physical and virtual materialities?* The publication discusses how young children make sense through exploration using a combination of different materialities in a facilitated project room (Figure 18). This was discussed based on three themes: (1) materiality, movement, and touching with light, (2) virtual materiality and touch, and (3) materiality, exploration, and experience.

The children used their past experiences of material touch to make sense of virtual materiality. In the encounter with a physical thorny twig, the children observed it and carefully explored it with their fingertips. As they explored it, they were enchanted by the thorn, and through bodily, facial, and emotional utterances, they expressed a curiosity about the material and the affordances of the physical thorn, which was touchable but still a bit dangerous. This was identified as a process of sense-making. In their exploration of a virtual thorny twig which was projected into the room, they used their past experience of touch in their new experience and in their exploration and play with virtual materiality. They pretended that a virtual thorny twig could prick, be grasped, and pulled off the wall. In this process the virtual thorn was understood as a representation of a physical one. The group of children used their emotions, imaginations, and past experiences in their exploration and play to make sense of the virtual materiality.

Through the study, I found that the children used similar strategies to explore both physical and virtual materiality. An example of this was one of the boys who attentively used his hands over and over again as he squeezed dried leaves between his fingers. At the same time, he was lighting them with light from a flashlight in the other hand. Later on, he used his flashlight to slowly move light back and forth into virtual materiality of the leaves. My interpretation is that the children observed, explored, and "touched" virtual materiality by using the flashlights in their hands to move light into virtual materiality.

The findings also indicate that children used their past experience of touch interaction with digital technology in their play to make sense and create new experiences in their physical environment. The study also showed that children manipulated, explored, and played with virtual materialities through moving their own bodies. They exploited and explored a spatial potential interacting with different materialities. An example of this was how they moved as if in a dance in front of a projection. They responded to each other's movements and were in interaction with the shifting of the materialities, making fluid and moving shadows in the environment.

The children also influenced and manipulated virtual materiality in their play by moving physical materials in the environment. They explored the affordances of actions and materialities in this environment through their perceptual capacities. These settings were also used to play in and create an imaginative world where the infusion and combinations of different materialities had a central role. An example of this was how a boy projected a photo of a buck skull onto a cloth hanging from the ceiling, while also asking his ECE teacher to move light back and forth into the projection and the physical surroundings. My interpretation of this is that the boy used his past experience of producing artistic expressions earlier in the day in this new experience. It seemed as if, in this setting, he had created an imaginative world where he became a scary figure, like a ghost, moving inside the cloth. The transformation of the materialities became an expression he used to stage his actions.

I found that projected virtual materiality changed from being perceivable as a representation, to being experienced as blurry colors and abstract shapes like an abstract painting in motion (Figure 18). This indicated how the digital technologies through interaction can shape the familiar, such as a thorny twig, and expand beyond children's sensory capacities and make different experiences and discoveries than the material world could offer alone. By including digital technologies in exploration, children can experience other artistic expressions and qualities of materiality than by exploring only the material. I developed an understanding of how the combination and experiences of different materialities offers new opportunities for explorative touch interaction, transforming and shaping children's experience of the material world through joint sense-making. It also illustrated how important children's past experience of material touch is to grasping virtual materiality.

Figure 18. A collage of children's explorations of different materialities. Photos and collage by Lovise Søyland.

5.4 Making Sense of Movement: A/r/tographic Explorations of Physical and Virtual Environments (*Publication IV*)

Publication IV was written as a result of Case 2 and Case 3 and answered the sub-question: *How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations?*

The study was analyzed and discussed through two main themes. For the first theme, I discussed *how haptic visuality—embodied photos and video—are central in making sense of movement.* Embodied photos (both my photos and the children's) and video can become another layer in developing an understanding of movement involving one's haptic perception, memories, and sense of intimacy. Through this study, I discovered that haptic visuality is essential for me as a researcher in making sense of a group of children's and my own movements in physical and virtual environments. This stresses how important it is to understand how the senses are interrelated, and especially how the visual and touch are interrelated, to gain understanding of movement in interaction with virtual materiality. A memory from my own childhood became a vital part of developing an understanding of children's movements and explorations of physical and virtual materialities. I connected a memory of touching a cactus from my own childhood in the process of developing my understanding of the children's experience of touching a physical thorny twig and a virtual one. The memory evoked emotions. I could recall the tactile and haptic experience and the composite sense of excitement of touching something I understood to be bit dangerous. Handheld and headband cameras became extensions of my body, and the audio-visual footage captured part of my embodied mode of engagement. The embodied photos and video provided access to study details in my own and the children's sensory experiences. My own past tactile and haptic experience was central in

analyzing haptic visuality dimensions of materiality. The children's own embodied photos were representations of their experiential experiences and added another layer to my understanding.

For the second theme, I discussed how *making collages is a reflective process for making sense of and expressing understanding of movements in physical and virtual environments.* Through the process of making digital collages, I developed an understanding of connections, similarities, and differences of embodied movement in physical and virtual environments. I found collage-making to be a valuable part of my a/r/tographic exploration, and I recognized the act as a reflective process of developing an understanding of movement and expressing my understanding and representations of haptic experiences. During the artistic processing and making of photo collages, features such as lines, contrasts, tempo, movement, and rhythm, which are closely connected to embodied knowledge, were used to express sensory experiences in an attempt to make them accessible to the viewer. Thus, the investigation of theme two illustrated that collages were integral to exploring and representing my sensorial experiences through surfaces and textures, all of which are linked to haptic visuality.

5.5 Summary of Key Findings

The study involving ECE students indicated that the opportunities to experience *different materialities simultaneously and to combine them* in different ways by using their own bodies, senses, materials, and digital technologies resulted in a distinct process of sense-making. Central in this process were the transformations and potentials of combining different materialities. The *unforeseen* had a key role in this process. An example of this was how one student's gaze, body, and emotions were understood to be in a close, *intimate relationship with a macro lens* attached to a touch device during intensive *haptic exploration* and enthusiastic engagement with materiality. *Something new and different arose* during her explorative process. The student was making new discoveries, engrossed in the process. In an explorative process with students and children, it is crucial *for teachers to have an open-minded and explorative approach to materiality* so it becomes possible to make new discoveries and artistic expressions. A creative process exploring materiality is a non-linear process that requires an openness to not knowing what the outcome will be. This process can create a feeling of resistance, and it takes courage to be in such an explorative rhizomatic process. This study indicated that sense-making emerges when students combine different materialities into new artistic expressions, and when digital technology is used to discover new aspects of materiality. When the material world is mediated through digital technology, as in the example of different

fluids blending, other properties of the materiality are being experienced such as fluid moving in slow motion. Such properties are difficult to experience without digital technology. The sense-making processes described above took place in collective explorative processes that shot out in different directions like a rhizome.

Two potential core paradoxes concerning sense-making and a person's physical engagement with the touch device and software of the picturebook app were found in Case 2. These can be defined as the *paradox of materiality* and the *paradox of interactivity*. In this context, touch and memory of touch were identified as central to bridging the gap between the physical and the virtual. Through the study, I developed insights into what facilitates being immersed in a virtual world. Moreover, previous tactile and haptic experiences of materials from the physical world revealed to be significant factors. In this process, virtual materiality and technological features evoked past experiences of physical materials and spatial experience. In this context, emotions were central in the sense-making process through haptic and tactile experiences in interaction with the app. Also, imagination played a central role in being able to imagine the feeling of, for example, haptic perceptions of a specific materials. The feeling of being immersed also aroused emotions and feelings of empathy and the interaction with the picturebook app evoked particular reactions and emotions. During the study, I found limitations in interaction with the app related to exploring predetermined possibilities for acting, and how the device influenced sensory perception. During the interaction, there was not an opportunity to create new solutions. I found that the app provided rich opportunities for cooperation; however, this cooperation extended only to co-option, not to co-creation. This is problematic given that sense-making is closely connected to the co-creation and creation of opportunities for imagination and interaction. The illusion of collaboration is more a requisition (co-opting) of certain actions. These findings are important for teacher's decision-making in facilitating children's sense-making processes with similar technologies.

Children used their past experiences of tactile and haptic perception of materials and their emotions and imaginations in their exploration to make sense of virtual materiality. The findings in Case 3 also indicated that children use their past experience of touch interaction with digital technology in their play to make sense and create new experiences in their physical environment. Through the study, I found that children used similar strategies to explore both physical and virtual materiality, although those materialities had different properties. The study also revealed different ways that virtual materiality can contribute to children's sense-making. One way is that virtual materiality can be a representation of a physical object, which affords new explorative potentials. A second way is that virtual materiality can be an abstract

materiality that is possible to shape and explore. It can be shaped by moving material objects in an environment, by moving bodies, and by adding other types of materiality such as light. During the explorative interaction, children were offered rich opportunities in their sense-making process to influence their surroundings, to make artistic expressions, and to make their own choices in relationship to and in interaction with different materialities, each other, and the adults. The main finding of the study was that the children's combination and experiences of different materialities offered them new opportunities for explorative touch interaction, transforming and shaping their experience of the world through joint sense-making.

In Cases 2 and 3, I developed an understanding of how I was able to make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic approach. I found that *haptic visuality—embodied photos and video—are central in making sense of movement.* Thus, I learned how haptic visuality and imagination are central to gaining an insight into a child's touch experience of different materialities. A memory from my own childhood became a vital part of developing this understanding. Audio-visual footage captured part of my embodied mode of engagement during interaction. The headband camera captured my bodily movement, rhythm, and sound in interaction with the picturebook app and in interaction with the children. This empirical data provided a means to understand what characterizes both my own and children's sensory experience. I also found that my own and the children's participation through photography became an integral part of our sensory experiences. I also gained insight into how an *artistic form of exploration such as making digital collages can play a major role in making sense and expressing an understanding of movements in physical and virtual environments*. During artistic processing, photos of bodies in movement, and features such as tempo, movement, lines, texture, and rhythm, which are closely connected to tactile and haptic ways of knowing, were used to express understanding of movement and make it accessible to the viewer.

6 General Discussion

The research question of this dissertation is: *How can explorative touch interactions with physical and virtual materialities facilitate processes of sense-making?* Based on the main findings of this study, I have identified six themes that form the basis of the general discussion. These themes are: (1) Tactile and haptic dimensions of materiality bridge understanding of the material to the virtual, (2) Emotions and imagination are embodied sense-making faculties during interaction with virtual materialities, (3) Virtual materiality can initiate new discoveries and shape the experience of the material world, (4) Digital technologies and strategies that provide opportunities for co-creation and exploration are essential to sense-making, (5) Joint exploration influences the process of sense-making with digital technologies in interaction with the physical environment, (6) Haptic visuality and artistic forms of exploration can deepen understanding of sense-making and touch interaction. Findings for themes 1–5 are related to the understanding I have developed of the sense-making process in interaction with different materialities; findings for theme 6 are related to the understanding I have developed through the ABR process. After discussing these findings, I will reflect on how these can have theoretical and practical implications for education. At the conclusion, I will reflect on the methodology of this study and then present suggestions for further research.

6.1 Sense-Making through Explorative Touch Interaction

6.1.1 Tactile and Haptic Dimensions of Materiality Bridge Understanding of the Material to the Virtual

While working on this dissertation, I have struggled to understand what materiality is. Ingold (2007, p. 7) describes how the materiality of a rock cannot be touched, even though it is a graspable material. In this way, the experience of materiality can be understood to be a process, a flow and connections (Ingold, 2007, p. 12; Pink et al. 2016, p. 13) between a person and an environment. My interpretation of this is that materiality is a processual concept, an overview of a phenomenon; it is not the phenomenon itself. I understand virtual materiality to be closely connected to matter and materials (see Browaeys, 2019). While physical materiality is in the realm of a visual matter and materials, the virtual is in the grip of what is invisible. I understand

this to be what Stenslie (2010, p. 128) describes as the material paradox of virtual realities and that virtual materialities are in a relationship of dependence with the material world. Thus, the virtual will not make sense to us without material experience. In this way, materiality is relationally conditioned (Damsholt & Simonsen, 2009, p. 17). It is a process emerging through our senses, a process of materialization (Pink et al. 2016, pp. 11–13). I suggest that tactile and haptic dimensions of materiality bridge our understanding of the material to the virtual, and that rich sensory experience from the material world is needed in order to be immersed in a virtual world and make sense of a virtual materiality.

The material paradox of virtual realities explains how we can make sense of a virtual materiality by previous experience and memories of physical environments and materials. In this context, the perceptual and sensory systems are primary (Fugate et.al. 2018). Imagine a forest covered by snow and that you move through this white cold material, stretching your hand out and touching the snow at the far end of a branch. In respect to material contexts, Springgay (2008, p. 21) describes the tactile and haptic as being in "a proximal relation with something." This means that when the opportunities to touch something are present, like the snow at the end of a branch, this will affect us. I will come back to how this can be explained later in this section. In tactile contact with a cold surface, like when the fingertip touches snow, our embodied minds register sensory information such as texture and coldness (Figure 19).

Figure 19. Surface of snow on a very cold day. Photo by Lovise Søyland.

This information is translated into electrical signals and interpreted (Groh, 2014, p. 5) as, for example, an icy surface which later can be reenacted in a new experience without the actual stimulus (Fugate et al., 2018, pp. 1–2). In other words, this sensation could, through memories and an act of imagination, be applied to a situation where the actual stimulus is absent. In line with Myin and Degenaar (2017, p. 91), I maintain that the tactile feelings of touching a cold surface are determined by particular patterns of previous experiences that a person has had touching cold surfaces.

Our embodied minds also respond in this way when we experience virtual materiality. This is because the experience of virtual materiality – the illusion – is triggered by previous somatosensory and visual representations in our brain maps (Groh, 2014, p. 69f). Our mental picturing (Groh, 2014, p. 205) or our imagination of, for example, snow against our skin or walking in snow is implemented by partially activating tactile and motor responses that would occur if we were actually feeling it. In this way, it is possible to "feel and experience" virtual snow. The feeling of physical snow is an experience with an active tactile and haptic feedback, while the experience of a virtual materiality is an experience with a *passive feedback*. Thus, even though a child, for example, can feel the glass on the surface of a touch device, this feeling does not correspond to the tactile sensations of an actual snowy surface. Borghi and Cimatti's (2009, p. 765) description of passive and active responses to environmental stimuli presents a framework for understanding physical and virtual materiality. I understand the physical experience of snow to be a richer experience, than the notion of such an experience, which I understand the experience of a virtual materiality to be. This underlines that "imaginative immersion" is central in experiencing virtual materiality (Susi, 2017, p. 192). Another perspective in this context is that the sense of touch is more immediate than vision. As Groh (2014, p. 20) states, vision is slower than touch because the interpretation of physical stimulus does not involve so many intervening steps. Thus, active haptic touch is more immediate than a tactile and haptic illusion such as the virtual materiality of snow. The experience of virtual materiality is more distanced because of the absence of the material compared with an experience of a physical materiality. The tactile and haptic experience of virtual materiality can be explained by *haptic visuality* (Marks, 2000; Pusch & Lécuyer, 2011, p. 1). The vision, the haptic illusion, and passive haptic feedback (Pusch & Lécuyer, 2011, p. 1) are interrelated with and depend on previous tactile and haptic material engagement to make sense of virtual snow.

Haptic perception and sense-making in a digital context are also related to interactivity and the mobility of a touch device. A person's physical interaction with a touch device and the software interactivity of the device are important factors in sense-making processes. Bodily

movement in interaction with the software of an app plays a key role in making sense of a virtual environment. An example of this is how I moved my body in interaction with the picturebook app. I moved the touch device and my body in positions like looking up into a virtual sky and around my own body's axis while looking into a virtual snowy forest. These movements immersed me in a virtual three-dimensional space and created the feeling of being inside a virtual forest looking up and experiencing falling snow. This can be explained by theory as to how memory is an integral part of building a sense of space (Groh, 2014, p. 189). Different areas in the brain make representations of where our hands are and how our body is positioned (Groh, 2014, p. 70). When I moved my body in interaction with the device and looked up into a virtual sky, my previous experience of bodily movement in a similar physical environment was crucial for making sense of and getting the feeling and experience of being immersed in a virtual world. Visual input receptors in a person's eyes form an image which is forwarded to the visual cortex as a brain map, and this makes a representation of the outside world (Groh, 2014, p. 69f). These brain maps of space are crucial in making sense of a virtual environment. Bodily movement triggers memories of past tactile and haptic perception and creates the feeling of being immersed in a virtual environment. This is an example of how cognition can be extended into virtual environments. This is in line with what Susi (2017, p. 3) has explained. Wilson (2002, p. 626) describes how cognition is extended, and how we offload meaning into the environment. My experience and understanding is that we also offload meaning into virtual environments.

This example of being immersed in a virtual environment also indicates how our senses are interrelated and operate in relation to each other (see Groh, 2014, p. 189). Noë (2006, p. 1) describes how "we enact our perceptual experience." Findings from my study indicate that we also enact our perceptual experience in virtual environments. As a result, the interactivity with the software can, through touch interaction, recall previous physical experience of interactions with materials and physical environment. O'Regan and Noë (2001, p. 940) state how our senses are interrelated and vision is a mode of exploration of the world, mediated by knowledge of sensorimotor contingencies. This indicates that our sense of space is rooted in combined interpretation of what we see and how we move our body in both the physical world (see Groh, 2014, pp. 52–56) and in making sense of virtual objects and virtual environments. The understanding described above makes me question how a person who has not experienced physical snow would experience the illusion of virtual snow, or how a child who has moved little in actual terrain will experience a similar virtual environment. These questions would be worth addressing in further research. However, the findings from my study suggest that it is

important for teachers to know about children's previous experiences with materials when they present children with materials in a virtual form.

Through my research, I have found that children have similar strategies and emotions when they approach physical and virtual materiality. I have observed how both physical and virtual materiality engaged them through vision and how this was triggered by touch. This is best described as haptic visuality imagining and affect (Pusch & Lécuyer, 2011). An example of this is how one of the boy's facial and bodily expressions communicated clearly how he was excited, curious, and filled with joy when he approached a physical thorny twig. My interpretation of this is that his thinking of touching gave him a bodily feeling of touching. I also observed the same phenomenon when one of the children approached a virtual thorny twig. The child hesitated for a moment before she laid her hand on a virtual thorn that was projected onto a wall.

Previous haptic experiences with materials bridge the understanding of similar mediated materials in children's exploration and play, and these aspects are important in their process of making sense of a virtual materiality. Children used their previous material experience to play with a virtual materiality, like pretending a virtual thorn could prick, indicating that they knew such or similar materials from before. They also used their past haptic experience of material affordances of handling material objects as lifting and pulling objects in their play and in their pretending to touch and pull virtual objects. An example regarding haptic perception and play is how one of the children pretended that the virtual thorny twig could be pulled off the wall while he was moving his body in a way that suggested he was pulling. This showed that previous haptic experience of a twig or similar materials and the two-dimensional illusion of the three-dimensional twig were connected in his process of sense-making and play. This finding emphasizes how previous somatosensory and representations are essential in children's sense-making of a virtual materiality, which underlines how children's past tactile and haptic experience of material touch influence their process of making sense of a materiality that does not have a physical form.

In this section, I have discussed how the tactile and haptic dimension of materiality bridge our understanding of the material to the virtual. Rich tactile and haptic experience of materials is important in making sense of virtual materialities when immersed in virtual environments. Due to the digitalization of materiality (Browaeys, 2019), I consider this understanding to be of great importance for education. Another layer in the discussion of digitalization is how surrounding surfaces are involved in sense-making processes. Thus, it is necessary, if we are to shed light on this area, to attend to Ingold's (2017, p. 99) discussion of

the renewed interest in surfaces in such disciplines as social anthropology and in visual and material culture, and to realize that surfaces are key conditions for generating meaning. Ingold (2011, p. 23) also interprets Gibson's theory of perception (1979) as only offering a weak recognition of the significance that the encounter between the fingertip and materiality of the world has for our understanding. This would be valuable to follow up. Thus, I will finish this section by stressing that Ingold's (2011, 2017) discussion, in addition to the knowledge of tactile and haptic bridging to virtual materiality described in this section, indicate that this area should receive more attention in education.

6.1.2 Emotions and Imagination Are Embodied Sense-Making Faculties during Interaction with Virtual Materialities

Emotions are seen as enactive and central in engaging with and making sense of the world and are part of our bodily coupling with the environment (Maiese, 2017, p. 231). Johnson (2007) states that imagination is part of and tied to a person's bodily process (p. 13), and emotions are processes of a person's environmental interactions (p. 66–67). I will now discuss emotional and imaginative aspects of making sense of a virtual materiality and virtual environments.

During this study, I found that children's emotional reactions were similar in their tactile and haptic exploration of physical and virtual materiality. An example of this is how the children's emotional experience tied to imagining being pricked (tactile experience) was evoked in experiencing both a physical thorn without touching it and a virtual thorn that could not be "touched." This can be explained by haptic visuality, but to understand more of this observation, it can be helpful to look into how past experiences are triggered. Schilhab et al. (2018, p. 2) describe how memories are stored as if they were sensed understood and emotionally felt. This means that children use their past experiences and emotions that are linked to similar settings in their new experience. This is because imagination involves our past experience both consciously and unconsciously. In other words, imagination is linked to both our implicit and our declarative memory (Purves et al., 2012, pp. 698–699) which means that our imagination is part of and tied to our bodily memory. In this way, emotions and imagination, as well as embodied interaction, play a key role in making sense of a virtual materiality and a virtual environment. Emotional experience is bounded up with feelings of various bodily changes (Maiese, 2017, p. 232), and emotions influence perception because the body is a vehicle of memory (Shapiro, 2017, p. 5). Experiencing virtual materiality can trigger previous

emotions and feelings to similar experiences of being, for example, pricked. This explains that children can have similar emotional reactions to a materiality of both a physical and virtual thorny twig. Central to this discussion is how digital technologies are constantly being improved and virtual materiality made available via, for example, touch devices that are getting sharper and with a better resolution. An example of this is *The Lion King* movie from 2019, where the texture of the fur is represented so vividly that it appears to be three-dimensional. I believe that such effects can make a dramatic impression on us. However, as described in the previous section, a virtual materiality is understood to provide passive feedback for a person. As result, a person's experience of a virtual materiality can evoke emotions, but emotions alone cannot be compared with experiencing active touch of, for example, fur as when holding your arms around a living creature.

Although a virtual materiality provides passive feedback it can initiate interactions, emotions and imagination. When one of the children from the study played and moved within a physical and hanging cloth with a photo of a buck skull (virtual materiality) projected on, I interpret the child's emotions and imagination to be central in his new experience. The child used his imagination when he pretended that he was a scary figure moving through the virtual materiality of a buck skull that were projected into the room. I interpreted his process to be emotional, and he was immersed into this process by his emotions and imagination. In other words, emotions and imagination can be understood to be central in children's exploration and play with virtual materialities.

Another aspect of virtual materiality and emotions is how a materiality in movement, such as a virtual character shivering, can create a feeling of empathy. This indicates that we can use our emotional experience from interacting with living creatures to make sense of a virtual character. Rizzolatti and Craighero (2004) describe how a mirroring system explains how we can be affected by looking at someone performing an action. During the study, I found that, through experiencing a virtual character's eye expression, movement, mimicry, and sound, my embodied knowing affected my emotions by triggering feelings of empathy and vulnerability. In this way, a software program can evoke certain reactions and emotions in a person. This is an example of how emotions are involved in experiencing virtual materiality. Another aspect to this is that our bodies serve as the *spatial* foundation of all emotional experience (Maiese, 2017, p. 233). A virtual materiality can initiate an emotional response related to a haptic experience of space, such as a feeling of being safe inside a house or a feeling of fear being outside surrounded by a dark virtual forest. In experiencing, for example, a virtual snowy forest, emotions can be triggered by somatosensory memories of feelings connected to walking in

snow, shivering, grasping snow, etc. Earlier unpleasant experiences with slippery surfaces can be awakened or pleasant feelings that create calm and harmonious moods from being outside. In such settings, a person uses past experiences and imagination to be immersed in a virtual environment (Susi, 2017, p. 192). Interactivity and bodily movement in interaction with digital technology can also influence the emotions through haptic experience of, for example, moving the body in a position for gazing at the stars while simultaneously looking at virtual materiality on a touch device. In such experiences, emotions provide the immediate capacities for making sense of a virtual materiality, and imagination is a key ingredient in being able to immerse oneself in a virtual environment.

In experiencing virtual materiality, emotions are connected to past experience – this involves a sense of being anchored in the past and situated in the present. In this way, emotions and feelings are *temporal* (Maiese, 2017, p. 233). Temporality is also an important feature of digital technologies, and it can influence our perception and emotions connected to experiencing a virtual materiality. When, for instance, the material world is mediated through video in slow motion, this can affect our emotions and provide another experience of materiality and temporality that the material world cannot offer alone. I will come back to this in the next section.

I found that emotions and feelings play a crucial role when a person *embodies a digital technology*. In exploring a picturebook app or using a macro lens on a touch device, the user's body is involved in an intimate interaction with the digital technology. When one student from this study experienced how the material world was mediated through a macro lens, the emotions and the tactile and haptic senses were involved in many ways. The student became totally engrossed in the process and flow of materiality in the situation. Her process of materialization can be characterized as a flow and connections (see Ingold, 2007, p. 12; Pink et al. 2016, p. 13) between her senses and her experience of physical and virtual materialities. I believe that some of her emotions and fascination were aroused because of the experience of the mediated materiality. In addition, her emotions might also have been aroused by a sense of wonder over the materiality – the phenomenon – which is experienced in the grip of visual matter and materials as well as by the virtual experience which is in the grip of the invisible (See Browaeys, 2019). The student described her experience as "falling in love with the macro lens," indicating that this experience was obviously emotional for her. In similar processes, emotions can affect and direct the person's attention and senses with or without the person's conscious attention (Maiese, 2017, p. 231). In this study, I noticed that emotions arose when digital technologies

gave the feeling of making new discoveries of the world or made us experience the material world in another way than we would have without the digital technology.

Thus, emotions and imagination are embodied sense-making faculties (see also Maiese, 2017, p. 231) that enable us to make sense of a virtual materiality. Imagination is closely related to the immediate and what is discovered through an explorative process. Gibbs (2006) describes how each case of perception involves a person's imagination of what it would feel like to, for example, touch an object or to move around in a terrain. Such feelings and the imagination of past perception are crucial also in making sense of a virtual materiality. The knowing body, through its senses, memories, emotions, and imagination is indispensable in our process of making sense of virtual materiality.

6.1.3 Virtual Materiality Can Initiate New Discoveries and Shape the Experience of the Material World

I have chosen to discuss this as a separate topic because I think it is important to highlight how touch interaction with digital technologies can be a way to grasp another materiality and have new experiences of the world.

In the study of the picturebook app, I found that touch interaction can evoke certain reactions and emotions, and I determined that the software of the app did not invite co-creation because of the limitation to influencing the narrative of the app. However, over time, the experience from my interactions with the app did affect my attention to my own moving body and to my material surroundings. I became, for example, more interested in my own movement during walks and running in outdoor terrain. I became aware of the surface of the forest and of being surrounded by three-dimensional physical space. I especially became interested in icy, frozen, and snowy surfaces; for example, I paid special attention to the icy surface when I was running with my shoes with spikes. I was also especially engaged in exploring snowy and icy surfaces with the camera lens of my mobile phone during these movements. It is possible that my perception had been affected in this way because I had been working with this study, its various themes, and this app for such a long time. This is a speculation, but it is also possible that bodily movement within a digital technology and a virtual environment can cause attention to one's own bodily movement within a physical environment. I concluded that my interaction with virtual surfaces and environments had made me attentive to my interaction with material

surfaces and physical environments. When I was outside walking in snow, I became more attentive than usual to the sound of snow being squeezed under the weight of my body as I walked and the cold air in my face, and how the three-dimensional landscape "wrapped me up." I am convinced that the lack of sensory information in interaction with the virtual materiality might have triggered my perceptions to become more focused on the tactile and haptic characteristics in the material world. This speculation adds a new layer to the discussion of the material paradox of virtual realities (Stenslie, 2010). It would be worthwhile to reflect upon this in other educational settings and follow up on this concept in a new study.

In the study involving teacher students, one of them used a macro lens attached to a touch device to explore different materials. The student moved around in the physical room with the macro lens attached to the touch device in her hands, and she used the macro lens to investigate the materials by moving her body and hands, while she was looking through it. The student verbally, emotionally, and bodily expressed that it was a new and exciting experience to explore the materials through the macro lens. She noted that the lens mediated a different experience of the materials and that it was an enriching experience. This is an example of what Ihde (2012, p. 376) describes as a way to expand awareness of what is possible through human perception by using a digital technology. When she experienced the world mediated through the macro lens, she made new discoveries. Browaeys (2019, p. 7) states that mediation can blur our original human perception. I would rather say that a mediator affects our perception and makes us experience other aspects of the world. However, this is an area that we should pay attention to, and we need to reflect upon how such transformations can have timely and dramatic influences on education (Säljö, 2010, p. 55). The example of the student described above illustrates the vast potential here. She moved around in the project room with a haptic attention, and she moved closer and further away from the leek flower with the touch device with the macro lens attached it, tapping the screen so that some parts stood out sharply in the photo. Her haptic visuality mediated through the macro lens, her past tactile and haptic experience of the materials, how the materials and digital technology aroused her emotions, and her movement in the room became integral to her experience. Her interaction with the digital technology became an intimate relationship within an open-ended creative process with the material surroundings. She made new discoveries of the materials by experiencing mediated materials and virtual materialities, while engrossed in her process.

What I found to be significant in the children's process of sense-making through exploring materialities was how they showed curiosity when they experienced the differences in materials that were both mediated not mediated. An example of this is how they had different

experiences when they explored a material directly, when they experienced a virtual materiality of the same object on screen, and when the same object was projected into the physical room in large-scale format. The physical materials and mediated materials had different affordances; for example, the physical thorn was difficult to lift and hold by hand, while the huge projected virtual thorn that initiated different bodily movements and interactions even though it could not be grasped with a hand. Thus, the children's tactile and haptic perception affected their experience in both exploring the graspable material and its virtual materiality. Digital technologies are objects which children can interact with in order to explore their physical surroundings and make new discoveries of their material surroundings. Their explorative processes can be open-ended and their exploration and grasping will require interactions. Digital technologies can be used as tools to influence, manipulate, explore, and experience material affordances that cannot be experienced without the technology. As Ihde (2012) notes, the mediation is part of expanding the awareness of what is possible through a person's perception. The combination and experiences of different materialities can offer new opportunities for explorative touch interaction and shape children's experience of the world. It can be a way to experience a materiality that the material world alone cannot offer.

Bodily movement, emotions, and time perception are essential aspects of experiencing virtual materiality and making new discoveries. In the first case, a student used time-lapse video while blending liquids (Figure 20).

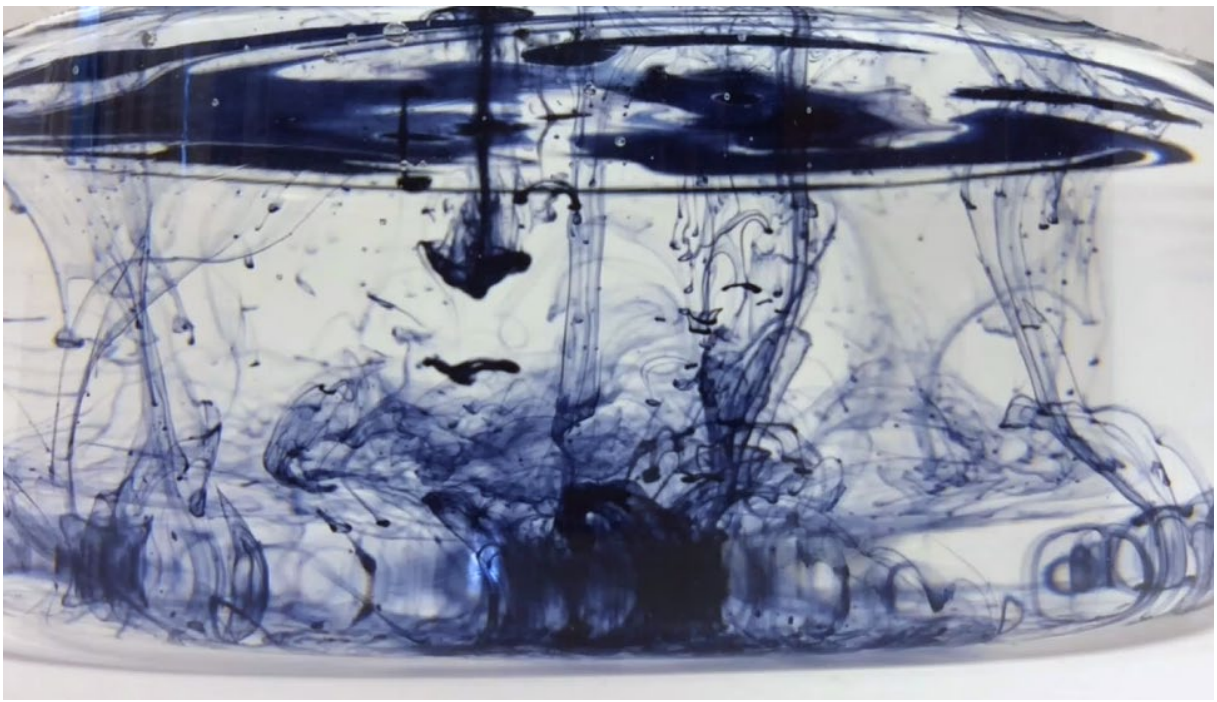


Figure 20. Student work: a still from the time-lapse video "Dancing Drops."

In the video, we can see fluid dissolving in slow motion. The student gave the video the title “Dancing Drops” because she connected her own or others’ bodily movements of dancing to the movement of virtual materiality. This indicates how her senses were interrelated and is an example of haptic visuality (Pusch & Lécuyer, 2011). Here, the visual is connected to her own bodily movement – and perhaps a viewer of the time-lapse video can experience how the visual is connected to their own experience of bodily movement.

The mediated material – the virtual materiality in slow motion – does something with the perception and the experience of illusions of materials on screen. In similar situations, the mediated material can affect the temporal experience, and we can experience a different aspect of the materiality – in other words, the temporality can shape how we experience the world. This can be explained by the spatiotemporal aspects in a digital media (Browaeys, 2019, p. 7; Elleström, 2011, p. 36), as to how mediators can modify our time perception and experience of space and provide a structure to sense perceptions. A time-lapse influences our experience of the materiality, and it can affect the experience by giving us more time to linger. It also adds that movement of shapes that is not reachable via our perception through the non-mediated material, and the mediator makes something visible that would be invisible without the digital technology. It affects our experience of time perception, the rhythm of materiality, and the properties of the mediated material. In this way, the digital technology can be used as a tool to translate an experience of a physical material into a poetically beautiful artistic expression. It can help us to discover new aspects of the material world.

6.1.4 Digital Technologies and Strategies That Provide Opportunities for Co-creation and Exploration Are Essential to Sense-Making

When I invited the children from this study into the large-scale arranged project room, they were offered multiple ways of interaction and to be co-creative in their exploration of materialities. They were provided rich opportunities to influence their surroundings, to make artistic expressions, and to make their own choices in interaction with different materialities, each other, their ECE teacher, and me. This interaction, and especially movement, played a crucial role in creating opportunities for new perceptions (Noë, 2006). In facilitating sense-making it is important that both ECE and ECTE teachers have an open-minded and explorative approach to materiality so it becomes possible to make new discoveries and artistic expressions.

A creative process of exploring materiality is an open-ended process that requires a willingness to accept not knowing what the outcome will be.

Digital technologies with a software that provide opportunities for co-creation are essential to sense-making. This kind of software can be called open-ended and invites children to create and explore (Bølgan, 2018, p. 99). In my examination of the virtual picturebook app, I evaluated the limitations related to the possibilities for exploration, predetermined the possibilities of interaction, and determined how the device influenced sensory perception in interaction with the app. The interaction was much like following someone else's path without the opportunity to create new solutions. The specific app provided rich opportunities for cooperation; however, this cooperation extended only to co-option, not to co-creation. That a digital technology provides opportunities for cooperation means that it invites cooperation with the features that the app developers have made. For example, you can shake the device to make snow fall off a tree. To be co-opted in this context means that you are invited into an environment where the rules are already set, and you have few possibilities to affect the outcome of the cooperation. Thompson and Stapleton (2008, p. 25) state that, to make sense, a person needs the opportunity to actively engage with the world to transform it into an environment that has meaning, significance, and value. This means we will have the opportunity to influence our surroundings, explore the world, and make discoveries that help us make sense of our place in the world. I acknowledge co-creation to be central in both adults and children's sense-making processes. Here, I use the term co-creation to denote having an opportunity to make choices and be involved in creating content in an app. I find this to be an important aspect to take into account when we are applying digital technologies in educational settings. Thus, it is important to make open-ended technology available for children so that they can be co-creators of content, to have the opportunity to choose from a large number of possible choices, and not be confined to the predetermined possibilities in the software. This is the explorative perspective which is highlighted in several studies as being all-important in children's use of digital technologies (Bølgan, 2018; Letnes, 2014; Waterhouse, 2013).

There are many positive aspects involved in what digital technologies as mediators can do when co-creation is taken into account. As discussed in 6.1.3, a digital technology can shape our experience of the material world and make us experience new aspects of it. A digital technology can make us experience representations from the physical world as virtual objects – an illusion of a physical object with illusory material qualities. Such is a reduction from a full bodily experience, and such an experience depends on a person's past experience with similar material objects, emotions, and imagination. Through this study, I discovered different

strategies for exploring virtual materialities in physical environments and virtual environments mediated by a touch device (Table 7). I found that the children's exploration of virtual materiality *largely involved their tactile and haptic perception*. Michaels and Palatinus (2017, p. 23) describe how the haptic sense depends on exploratory movements to make information available in physical surroundings. The children's tactile and haptic perception was crucial in their exploration even when the materiality was virtual. They used their tactile and haptic perception, emotions, and imagination to make sense of virtual materiality. They mentally and bodily accessed their past touch experiences of handling material objects to explore and play with virtual ones.

The children explored virtual materiality by moving their own bodies and material objects in an environment with virtual materiality. They manipulated virtual materiality by moving material objects like a transparent piece of cloth hanging from the roof, and by adding other materials, such as light, to the room. This was a way to explore and experience the combination of physical and virtual materialities and to be involved in co-creation. Their bodies became important in exploring the materialities in the environment. They manipulated virtual materiality by moving their own bodies, by blocking the light from a projector with their hands, and by moving as if dancing in front of the light from the projector creating shadows. This surely exemplified the *strategy to explore and experience the combination of materialities and part of a co-creative process*. It is also important to acknowledge that virtual materiality made available through a digital technology can be an abstract materiality which is equally possible to manipulate and explore. The children's exploration and manipulation of abstract virtual materiality can be a way to make artistic expressions and be invited into co-creation. Thus, bodily movement (tactile and haptic) in interaction with virtual materiality, virtual objects, and virtual environments supports the sense-making processes.

A main finding in this research is that digital technologies, such as a camera software app and *elementary digital technology* like a projector, can create opportunities to be explorative and *co-creative*. However, the innovative use of software with the virtual reality picturebook app, in the context of exploration and co-creation, only provided opportunities for cooperation that extended to co-option. In order to facilitate sense-making, it is important to take time to stop for reflection, while being sensible of the present and responding to what happens in a specific context. The children's c*ombination of physical materials and digital technologies* can provide them with opportunities to be explorative and co-creative. There is a potential to combine materials and digital technologies in different ways to facilitate sense-making. I identified potentials to experience the combination of different materialities working

with propositions, different textures, projection of virtual materiality onto materials, qualities like transparence, and placement of objects in an environment. In Table 7, I present discoveries from this study and implications that I encourage teachers to take into consideration to support children's sense-making with digital technologies. I will return to this in section 6.2 when I present the practical implications of this study.

Table 7. Discoveries of what digital technologies as mediators can do, strategies exploring virtual objects and virtual materialities, and suggested strategies.

Discoveries of what digital technology as mediators can do	- When moving within a digital touch device, the world is experienced and mediated through it. - We can experience new aspects of the material world. - Our experience of the material world can be shaped and transformed by what we are able to perceive through the spatiotemporal potential of materially. - We are able to experience representations from the physical world as virtual objects – that is, illusions of materials. - We can experience mediated virtual environments through projection and through touch devices. - We can engage with virtual objects and virtual environments in a reduction from full bodily experience dependent on past experience, emotions, and imagination. - Mediated virtual objects can invite us into imagination and haptic exploration. - Mediated virtual objects (or characters) can evoke emotions, empathy, and feelings.
Discoveries of strategies exploring virtual objects	- Children use similar strategies in exploring physical and virtual objects. - Children can experience virtual objects as representations of the physical world. - Children use past tactile and haptic experience from handling material objects to explore and play with virtual objects. - Children use past tactile and haptic experience with digital technology (e.g., pushing an iPad button) in exploration and play with virtual objects projected into a physical environment. - Children use imagination and haptic perception to make sense of and explore virtual objects.
Discoveries of strategies exploring virtual materialities in physical environments and virtual environments mediated by a touch device	- Children explore virtual materiality projected into the physical environment by moving their own bodies and "touching" virtual materiality in space. - Children move material objects with a virtual materiality projected onto them in exploration and play (e.g., transparent piece of white cloth with a buck skull projected onto it). - Children shape the experience of materiality by moving material objects and their own bodies. - Children move their bodies to manipulate virtual materiality and light from a projection. They play with different materialities and make shadows. - Children manipulate virtual materiality by adding other materials such as light. They manipulate virtual materialities by moving flashlights in their hands. - Children explore and manipulate abstract virtual materiality. - Children explore spatiotemporal potentials of virtual materiality through interaction. - Bodily movement in a physical environment in interaction with a virtual environment mediated through a physical device is central to making sense of a virtual environment.

Factors to take into consideration and suggested strategies	- Teachers must be aware of how virtual objects can trigger imagination and emotions. - Teachers must pay attention to and take children's previous tactile and haptic experience of touching three-dimensional objects and materials into account in exploration and play with virtual materiality. - Teachers must facilitate children's exploration of tactile and haptic exploration of materials like snow to enrich their sensory experience with a virtual materiality. - Teachers must take tactile and haptic aspects into consideration when facilitating sense-making; for example, children need space to move in physical environments in interaction with virtual ones. - Teachers must take physical condition and possibilities for bodily movement into consideration in facilitating sense-making in interaction with digital technology. - Teachers can facilitate children's tactile and haptic material experience while they are in interaction with a virtual environment in an app, for example, having children walk on snow while interacting with a virtual snowy landscape. - Teachers must insure that children experience rich sensory perception in advance or after interaction with virtual objects or virtual environments. - Teachers can project a virtual world (like Wuwu's world) into an environment. In this way, children can be given the ability to walk into it and to experience bodily movement and haptic exploration in a physical environment. - Teachers must take the spatiotemporal factors of exploring materialities into consideration in facilitating sense-making. - Elementary digital technology such as a camera app can invite children into co-creation and facilitate sense-making.

6.1.5 Joint Exploration Influences the Process of Sense-Making with Digital Technologies in Interaction with the Physical Environment

Sense-making occurs to various degrees from orientation of individual sense-making to joint sense-making (Di Paolo & Thompson, 2017, p. 75). Through this study, I found that interactions between students, between children, between children and adults, and between students and teachers influenced the process of sense-making with digital technologies in interaction with the physical environment.

I found my identity and involvement as an a/r/tographer to be important to the process of joint sense-making in interaction with both students and children. In several of the teacher students' explorations, I observed that there was more resistance in their processes than in the children's. In fact, it was a new concept to them to explore without knowing what the outcome would be. According to Shusterman's (1999) explanation of sensory attention, in explorative processes, a person can direct the senses to experience, for example, artistic qualities or to discover the essential in a context. In the settings with students, it became important for me to initiate the process together with them, to make them aware of some of the possibilities to

explore the combinations of materials and digital technologies, and to show them what the technology afforded in the situation. An example of this was when I put my hand into a glass bowl with water and moved my hand while videoing it and projecting it into the physical environment. Such actions were important contributions because they motivated and initiated ideas and highlighted some of the affordances in the material–digital environment. I used my earlier experience of knowing more about the material and digital technological affordances than the teacher students and the children as a means to guide them. In some instances, I understood what the children or students were trying to do, or I saw potentials in what they could do, for example, when making new artistic expressions or experience artistic qualities. I used my a/r/tographic knowledge to interact, to initiate exploration, and make sense together with them.

Thinking and interaction through exploration gives power to rhizomatic movements and to joint sense-making. The example described above where I initiated actions is an example of how an interaction can branch into and initiate new processes of explorations in an environment. The students needed more prompting and guidance toward getting into the mood and spirit of exploration than the children did. During interaction between the students and the a/r/tographers, some of the students needed a reminder to look around and observe what other students were doing, and in some settings I needed to initiate concrete actions. After a while, when students got into the mood and flow, using their senses and focusing on the explorative, it was as if things started "to boil" in the large project room. Something was about to extend like a rhizome – new experiences, artistic expressions, and discoveries branched out. Their attention was shifting from individual to joint and back to individual sense-making (see Di Paolo & Thompson, 2017, p. 75), and I could begin to withdraw from my role as a guide. I believe that my flexibility was valuable in these settings in addition to improvisational teaching and the ability to "read" what the current situation required.

The children had a more spontaneous approach to exploring the materials and digital technologies than the teacher students did. It was as if they could not wait to join in and investigate what was in the large-scale project room. They moved together in small groups most of the time, and when they explored individually, they did not focus for such a long time. An example of this is how they explored virtual materiality projected into the room by moving their own bodies and moving flashlights in their hands. They paid attention to each other's movements while they were moving their bodies as if in a dance, as they simultaneously made flashes of light and shifting shadows. They combined, shaped, and explored the physical and virtual materialities through joint sense-making. This was what Di Paolo and Thompson (2017,

p. 75) describe as an embodied process of active regulation of the coupling between a person and the world and in social interaction – and that settings such as this with the group of children open the possibility of sense-making being a joint undertaking among the interactors. I experienced that the children and I were attentive to each other's initiative and movements. Sometimes, I used my bodily language to give them a hint such as looking around, or I showed them something concrete such as moving a material artifact to see how it reflected light or what would happen when we moved a projection along the wall. But mostly the children initiated different explorations and movements in the environment and involved me and their ECE teacher in joint interaction and exploration.

In one of the instances with the children, I identified one boy's exploration of different materialities. He had previously explored a buck skull with his hand, lifted it, used his fingers to feel the teeth of the skull, and he had taken different photos of it with the camera app on a touch device. He asked me if I could project one of his photos of the skull into the physical environment while also asking his ECE teacher if she could move a flashlight beam back and forth on the projected materiality and physical environment. The boy used his imagination and the different materialities became an expression he used to stage his actions as a scary figure. He explored the affordances of actions and materialities in this environment through his perceptual and actionable capacities. Through joint interaction together with me and his ECE teacher, the affordances became part of the act of perception (Chemero, 2010, p. 186).

Noë (2006, p. 1) emphasizes that perception is something we do, and it is not something that just happens to us, or in us. This underlines the importance of exploring materialities in joint interactions in arts and crafts educational settings. Michaels and Palatinus (2017, p. 23) state that the concept of affordances "reflects the intimacy of perception and action." This perspective is valuable in material–digital settings with both children and students. This is important because materiality is a process, a flow, and a connection (Ingold, 2007, p. 12; Pink et al., 2016, p. 13) between a person and the environment. For me as an a/r/tographer, this means that this is something we need to know about our surroundings, and that this has to be a focus in ECE. We need to understand that, tactile and haptic perceptions provide us with information that is, in additional to visual, essential for making sense of materiality (see Michaels & Palatinus, 2017, p. 23). Open-ended processes open up the possibility of joint sense-making among us as interactors in the material–digital environment. Thus, joint sense-making results from joint explorations, and new discoveries are made through experiences that branch out like a rhizome.

6.1.6 Haptic Visuality and Artistic Forms of Exploration Can Deepen Understanding of Sense-Making and Touch Interaction

Polanyi (1966/1983) describes how our experiential knowledge is tacit, meaning that it is silent if we do not find a way to express it. In the context of education and educational research, we need to better understand others' and our own experiential knowledge. During this study, I found embodied photos and video to be key in making sense of touch interaction with physical and virtual materialities. I also found that artistic forms of exploration, such as manipulating photos and creating collages, contributed to developing an understanding of others and my own sense-making in interaction with different materialities.

Haptic visuality is a foundation for the discussion in this section. It describes how previous experience of tactile and haptic perception can trigger visual feedback and create an illusion of tactile and haptic experience (see Pusch & Lécuyer, 2011, p. 57). It is also central in the discussion to use theory that describes how visual experience is dependent on and relates to our memories and our interrelated senses (see Rose, 2016, p. 34). MacDougall (2005, p. 3) describes how photos are images of the body behind the camera – that photos "refer back to the photographer at the moment of their creation." I relate to this in the context of this study; however, I prefer to call them *embodied photos*. The reason is because all the photos in this study were taken by subjects with an embodied mind with a handheld camera. In addition, I prefer to refer video captured in this study with a headband camera as *embodied video* (this could also be video from a handheld camera or camera attached to other parts of a person's body). When I used a headband camera, the camera recorded my interaction with the children, the digital technologies, the materials, and the environment.

I found my own *embodied photos* to be important in studying and reflecting upon my own sense-making process in interaction with physical and virtual materialities and environments in Case 2. My photographing, sensing, and reflecting helped me understand how tactile and haptic experiences bridge the physical to the virtual, as described in the section 6.1.1. The camera became a tool I used over a period of time (3–4 weeks) when I moved in outdoor snowy terrain and photographed tactile snowy surfaces. These embodied photos have been part of my study since the winter of 2017. My photography was not a planned part of my data collection for exploring the virtual picturebook app; instead, it was a natural outgrowth of my a/r/tographic exploration. My attention was drawn to photographing snowy surfaces and environments while moving on and through the environment and touching the material in different ways. This illustrated how tactile feelings of virtual materialities of snow were

determined by particular patterns of experiences and feelings I had with previous touching of cold surfaces. However, I did not include these processes as data in Case 2, simply because it did not become clear to me that this had been a valuable part of my data collection and analysis process before the article was published (see Søyland & Gulliksen, 2019). However, I was reflecting on the material paradox of virtual realities over a long period of time, I was writing notes based on these experiences, and I stored the photos systematically by date.

Embodied photos have also played a role in my study of the ECTE students and children's touch interactions with different materialities. During interactions with others, the materials, digital technologies, and the environment, I have been closely involved in the joint explorations. In these instances, I was present and part of these moments of engagement and sense-making, as I was observing, positioning myself in the room, and searching for the right angle aiming to make good compositions while taking photos. The photos can be understood to be "frozen moments" where I have sensed and recorded something related to the aim of this study through my embodied involvement with these contexts. This is in line with Pink (2015, p. 125) who describes digital technologies such as cameras as part of the ethnographer's embodied mode of engagement. It is challenging to describe what I sensed, exactly why I found these moments that I froze valuable, and in what way my haptic visuality was important in those moments. As shown in Figure 21, it was a moment where I was close up observing how two children and their ECE teacher explored the material and materiality with their senses, using their hands and light from flashlights. This was a moment I understood to be a joint exploration filled with curiosity and exploration of the material affordances. However, for me, this photo was also a reflection of how children use their hands when they hold a touch device, and it made me question how a touch device can trigger similar curiosity of materiality and how children and adults explore digital technologies in joint explorations. The camera was a part of me directing my attention and my senses in those instances, and the embodied photos became an integral part of my reflections on how physical and virtual materialities facilitated processes of sense-making.

Figure 21. Two children and their ECE teacher (in the middle) exploring a material (loofah sponge) with their hands and a light from flashlights. Photo by Lovise Søyland.

Thus far, I have described my own embodied photos; however, this study also included the children's photos (Case 3) and my co-authors' photos (Case 1). In the first case, we did not use video in the data collection, but we three a/r/tographers with our three different embodied minds were present during the interactions and photographing. In the analyses and discussion, these different views and perspectives were essential as a form of data triangulation. In the third case, I also included the children's "participatory photographs" (Clark, 2014, pp. 200–203; Holm et al., 2019, pp. 316) in the analysis. The children's embodied photos provided me with nuances in how they moved and what they were occupied with. Their photos furnished me with information about the body–mind behind the camera in interaction with the environment and others in the room. When I studied the children's photos, their "frozen moments," my haptic visuality in conjunction with my memories from our joint interaction, and explorative setting were important in developing an understanding. I connected the photos to my own past experiences, emotions, and imaginings as well with what I had learned from my study of embodied cognition theory. Including children's views and experiences through photos in a research setting such as this is what Clark (2014, pp. 200–203) describes as a mosaic approach. I found the children's embodied photos to be fruitful in gaining a deeper insight into sense-making and materiality. In future work and similar research settings, I will definitely consider having the participants' photos play an even greater role.

I will now delve into making sense of *embodied video*. I also found the headband camera to be a useful device for studying both my own and the children's touch interactions in the different settings. It captured nuances in how I moved, my breath, where I looked, sounds of movements, and, for example, how the children and I explored the surroundings together. An example of this is how the embodied video provided me with information about the children's feet while moving at a high pace, and how I followed their movements toward a virtual object in the physical environment. Their movements and the sound of their movements provided me with information about their engagement and how they were eager and excited to explore and touch an object. Another example concerns when I analyzed the embodied video from my own exploration of the picturebook app. In this process, the embodied video made me more aware of my own sensory experience than I would have been without it. In studying the embodied video, I could follow and reenact my own movement like when I moved my body in the physical room in interaction with the virtual one. I could study small details, such as how I moved my body and my head "when the virtual snow slowly fell down." I studied how I held my breath for a second when I was immersed in the snowy sky, and how I made an almost inaudible sound when I was impressed by the beautiful experience of the virtual snow. The headband camera captured aspects such as speed, movement, and framing, and the sound of my moving body in interaction with the virtual environment, while I was moving in the physical one. This is in line with how Harwood and Collier (2019, p. 54) describe how such cameras can provide information in a research setting. The embodied video furnished me with nuanced information from the settings, and became an important part of my analysis. It is difficult to express exactly what I sensed and understood. But it was about studying small details that were hardly visible or audible but still important in developing an insight into interactions, such as a child's eyebrow moving, or sounds of excitement communicated through breathing, a giggling sound, or a child slowly moving one of his fingers in the direction of a material artifact. Thus, embodied photos and embodied video provided me with important information of tactile and haptic experience in the different research settings. In line with Pink (2015, p. 168), the photos and video clearly illustrated the significant role of touch and tactile ways of knowing. I especially found that the "frozen moments" of embodied photos provided me with information about the embodied mind behind the camera in an intimate, entangled moment of a situation. The embodied videos were close to my own sensory experiences of movement and sound, in interaction with the environment, children, materials, and digital technologies. These made me aware of details that I did not sense during the actual interaction.

During this study, I found *collage making* to be a reflective process to make sense and express understanding of touch interactions with virtual and physical materiality (Figure 22).

Figure 22. A collage of my reflections on tactile snowy surfaces.
Collage by Lovise Søyland.

This is in line with how Scotti and Chilton (2019, p. 360) describe collage making as a way to conceptualize ideas and reflect upon them. In examination of the picturebook app, my attention was drawn to my own tactile and haptic experience of physical snowy terrain and to my emotions while being immersed in and surrounded by snowy forests. My collage making was primarily a part of my reflective process; it was not my attention to share this with a viewer. Nevertheless, I think they contain information about my reflection and my understanding of materiality that can be experienced by a viewer. Figure 22 is a collage of my reflective process of the tactile feeling a snowy surface can give, which was part of my process of learning how we bridge our understanding from the physical to the virtual. As shown in the figure, what I did in the making process of this collage was to add colors such as pink to create a warm–cold contrast to the white snow and to the texture of the frozen branches covered with snow.

This was part of highlighting my tactile feeling of the materiality. I used a color tool in the Procreator app to drop colors into the texture of the background. I also cut out parts of the

photo, and adjusted light to make a contrast that was soft and not too sharp between the snowy texture and the background. The organic texture – the branches covered with snow – aroused positive feelings in me, such as feeling safe, and association to a nest represented something protective. During the examination of the app, good emotions related to being surrounded by a snowy forest, and more ambivalent feelings such as being inside a dark forest emerged. My collage making was a reflection of the emotions and feelings of being immersed in a virtual environment and how the materiality initiated emotions in me. This was connected to my past experience, and I also explored these feelings while moving in the snowy terrain. Figure 23 is another example of what I did in the collage making process.

Figure 23. A collage as an expression of my experience of moving through the virtual forest and being surrounded by the dark. Collage by Lovise Søyland.

This collage is composed of different photos. The dark field in the foreground was added to create a contrast to the house and the snow in the background of the collage. It was a reflection of the ambivalent feeling of coming out of a dark forest. I created this contrast between dark elements and the little house to explore the feeling of having to rush out of the forest before it grew dark and to get inside of the safe and warm house. These collages were exemplary representations of my tactile and haptic knowledge of materiality.

The arts-based methodology – a community of knowledge where it is recognized that research processes can have the same qualities as artistic processes – gave me the courage to work with artistic processes in this study. Some of my processes were planned, such as photographing while interacting with children to document moments of sense-making. Others emerged intuitively during my quest to make sense of the phenomena of physical and virtual

materiality. ABR methodology is increasingly being recognized in educational research (Leavy, 2019, pp. 6–9). I suggest that multiple ways of knowing, such as sensory, imaginary, and emotional processes like collage making, should also have broader recognition in educational research. Working with the artistic process based on the empirical material has been the foundation of this dissertation. An artistic approach to handling the audio-visual empirical data has been productive for me as an a/r/tographer as it has allowed me to use my senses, subjectivity, and emotions in developing understanding of both my own and others' sensory experiences. These are qualities that Bresler (2006) highlights as being necessary in ABR. The ABR methodology gave me an opportunity to study the tacit and sensory in children's experiences. I think this is crucial in a time when the sense of touch has largely been neglected (see Jewitt & Leder Mackley, 2019, p. 92) and the sensory and emotional have been downplayed in children's educational settings (Mangen et al., 2019, p. 242). I believe it is essential for the educational research field to continue to take advantage of and develop artistic forms of explorations in both analyzing and expressing understanding of sensory experience.

6.2 Practical Implications

The aim of my qualitative research has been to make a meaningful contribution to the children, teacher students', and my own experience of exploration of materialities (see Stake, 2010, pp. 56–58). In qualitative research, the findings cannot be applied directly, but they can be useful and relevant in related situations. In this section, I discuss four themes that I consider having practical implications for ECE and ECTE. They are as follows: 1) Physical materials and manual technologies are needed in education, 2) It is central that teachers apply digital technologies and strategies that invite others to participate in joint exploration and co-creation to facilitate sense-making, 3) It is important that teachers in both ECE and ECTE develop a material–digital explorative practice, and 4) It is important to continue to develop and apply arts-based methods that can contribute to understanding sensory experience in interaction with digital technologies. The fourth theme is related to suggestions regarding research practice.

The first practical implication of this research is that *physical materials and manual technologies are needed in education.* In a time when children experience virtual materialities more often than ever before, it is important that children experience rich sensory experiences with their material surroundings from an early age (including using manual technologies to explore materials). This is important for their development and for the value of material exploration itself, and for being able to connect virtual materiality with the experience of

physical materiality to make sense of it. This understanding is important for ECE teachers, and I recommend this to be a central issue in ECTE. The surface of a digital technology provides less sensory information than a surface of a physical material such as the bark of a tree. A virtual materiality of a tree cannot be grasped – it is not possible to move around it, climb it, or lie down under it. This knowledge is crucial to be aware of when teachers facilitate children's sense-making process with digital technologies. Therefore, it is indispensable that tactile and haptic experiences from the material world are brought into exploration of virtual materialities and *vice versa* – that is why it can be said that tactile and haptic experiences bridge the gap between the physical and the virtual.

The second practical implication of this research is that it is essential *for teachers to apply digital technologies and strategies that invite children and students to engage in joint exploration and co-creation.* Initially, I stressed that there have been few empirical studies on what significant benefits digital technology has for children's learning when it is used wisely (Bølgan, 2018, p. 15; Chaudron, 2015; p. 11; Johansen, 2015, p. 32). To use it wisely is a question of definition; however, the exploratory and creative aspects of the digital practice in ECE have been highlighted its value (Bølgan, 2018). I consider it important to apply digital technologies that are open-ended, and which promote co-creation where it becomes an opportunity to influence the outcome of an explorative interaction. This implication requires that ECE and ECTE teachers have the knowledge about which kinds of digital technologies should be included in education. During this study, I found that elementary digital technology, such as a camera, a video app, and a projector, can create opportunities for being explorative and co-creative. This means that technology does not necessarily have to be particularly advanced to facilitate sense-making processes with children and students. What teachers should rather focus on is the action potential of the technology and how the technological affordances can be explored through joint interaction, in other words, how to use digital technologies in explorative ways, including their haptic, material, and spatial considerations. I consider this to be a digital practice that takes the importance of experiential knowledge into consideration (see Table 7 for sense-making strategies and suggested strategies). The explorative and co-creative aspects are important in the discussion of digital practice that can be developed into what Letnes (2014, p. 8) terms a reductionist understanding of digital competence, which can be limited to something predefined and measurable within the scope of subjects. There is also an imperative in digital technologies where the goal is to increase pace and efficiency in children's learning and to eliminate the complexity of a phenomenon. I think that this imperative is largely opposed

to the most important values and perspectives in arts and crafts education, which often is about slow, deep, and present processes.

I believe that teachers in both ECE and ECTE should see teaching with digital technologies as an invitation for exploration. And, I suggest that it is taken into account that the tactile and haptic perceptions are the most important senses for making information available through exploration (see Michaels & Palatinus, 2017, p. 23). Explorative practice should have an agenda that, for example, includes the in-depth study of a phenomenon rather than having specific goals or learning outcomes. Teachers should practice improvisational teaching with digital technologies and be able to see possibilities that are not actual and base their actions upon this. In this way, the encountering the unforeseen and making new discoveries can be included in practice. I would argue that the presence of teachers is important in both ECTE students and children's interaction with digital technology. Both ECTE and ECE teachers must dare to get a bit lost in explorative processes together with students and children. Teachers must practice going beyond what can be controlled and be open to what may arise during an explorative process. This is what Biesta (2013, p. 2, 2018) means when he stresses that education is about lightning a fire and not filling a bucket. Thus explorative practice can include the unforeseen – which Brunstad (2013, 2018) argues as being intrinsic to education. My interpretation is that a digital practice would benefit from a focus on joint explorative interactions between ECTE teachers and students and between ECE teachers and children. An example of this is how I often have experienced that, when I talk with ECTE students about artistic and explorative processes, it is sometimes hard for them to understand what I mean. However, when I do something, such as moving a projection onto the ceiling of a room, or curling up a big piece of paper instead of talking about the material properties of paper, they understand in an emotional-physical-cognitive way. This kind of practice can create impulses to engage in new interactions and explorations, which in turn can provide new discoveries. I would recommend being aware of how students can benefit from joining explorative processes together with fellow students and teachers in digital practices that include explorative elements. This way of interacting with the environment together with children in ECE is normal, but perhaps it is not so prominent in exploration including digital technologies. I consider it to be crucial for both ECE and ECTE teachers to have an open-minded and explorative approach to materiality so it becomes possible to make new discoveries and artistic expressions.

The third practical implication is that I recommend *teachers in both ECE and ECTE to develop a material–digital explorative practice*. Initially, I described a digital–material dichotomy, and how academic scholarship within design and anthropology has developed the

digital and material as two different concepts and that this is seen as problematic (Pink et al., 2016, p. 6). In section 4.1.2, I also described my personal background for doing this research and how it was anchored in an experience of a partial digital–material dichotomy among colleagues in my field when I started working with this dissertation. Based on findings from this study, my interpretation is that the material–digital should be treated as inseparable in explorative and creative arts and crafts processes. This is in line with what Pink et al. (2016, p. 7) describes in the practice-based disciplines of architecture and design. Thus, ECE in general should treat the material and digital as inseparable and consider this perspective in facilitating children's sense-making with digital technologies. I do not claim that such practices do not exist in ECE and in ECTE, but I think that there still exists a digital–material dichotomy in this field.

I recommend that a material-digital explorative practice should be influenced by the material tradition in ECE and arts and crafts educational thinking. I suggest that we should aim to develop strategies that focus on sensory experience, especially haptic and tactile perception. In the context of making sense through interaction within a material–digital practice – arts and crafts strategies have a lot to offer. It has been documented that ECE largely pursues a reproduction culture, and that it is necessary to shift the focus from consumer to producer and explorer (Bølgan, 2018; Letnes, 2014; Waterhouse, 2013). The one-sided focus on literacy and mathematical understanding in the use of digital technology in ECE (Jæger & Sandvik, 2019) is restrictive and shortsighted. I think that children should exist in a material–digital culture where teachers are active together with children in joint exploration. Initially, I pointed to how the material turn (Barad, 2007, Lenz Taguchi, 2010) can be understood as a counterweight to the digitalization of materiality. With more knowledge about how the different materialities affect humans, teachers can contribute to breaking down dichotomies such as "for or against technology" (Mangen, 2016, p. 471), and the digital versus the material (Pink et al., 2016, p. 6), and rather exploit potentials to explore and make new discoveries with both physical and virtual materialities. As I noted earlier, materiality is a process; it is relationally conditioned, and not something defined but a process which emerges through our sensory perception (see Damsholt & Simonsen, 2009; Ingold, 2007; Pink et al., 2016). Barad (2008, p. 120) famously stated, "The only thing that does not seem to matter anymore is matter," and this put the importance of materiality on the agenda. I would argue that teachers also must pay attention to how virtual materiality matters. The most important aspect of a material–digital practice is the explorative potential in experiencing how virtual materiality can be shaped by moving material objects and bodies in a room (spatial–temporal potential), how artistic expressions can be made in different combinations of physical and virtual materialities, and how this kind of experience

can make new discoveries of the world. This study highlights possibilities for children and students to use digital technologies in artistic exploration. It describes the opportunities to explore, combine, and interact with different materialities and the role of their imagination and emotions in similar contexts. It is noteworthy that the makerspace movement (Burke & Crocker, 2019; Clapp et al., 2016) – where children and students are invited to explore and make things combining materials and manual – and digital technology have a lot to offer in the context of developing a material–digital practice. I acknowledge that this movement can contribute to promoting children and students' sense-making through exploration and co-creation. It is hopeful for ECE and ECTE that policy documents (MER, 2017) have acknowledged the value in exploration and artistic forms of expressions connected to use of digital technology. However, it has to be remembered that teachers cannot exactly plan how students and children will explore or make sense in a facilitated material–digital environment. We can try to imagine, and, to some extent, be familiar with the material–digital affordances, but during the sense-making process teachers must be open to embracing the unforeseen. Thus, I encourage ECE and ECTE teachers to work with open-ended processes that include materials and digital technologies.

The fourth practical implication is that it is *important to continue to develop and apply arts-based methods that can contribute to understanding sensory experience in interaction with digital technologies*. Several researchers within the field of children's learning with digital technology argue that studies would benefit from greater methodological diversity (Mangen et al., 2019, p. 242; Kucirkova et al., 2019, p. 3). I think it is especially important to continue to develop artistic forms of exploration to develop knowledge in this field (see also 6.1.6.). In this context, I find it valuable to invite children and ECE staffs to be participants in studies so that we can learn from their experiences and understandings. I share this opinion with Clark (2014). Thus, ECE and ECTE would benefit from close cooperation with each other through, for example, partnerships between universities and ECE, and with a focus on both practice and research. This has been a focus area in the Norwegian educational community in recent years, which I consider to be a positive development for education. The goal in such a partnership should be to further develop a material–digital practice with a focus on the tactile and haptic, co-creative, and explorative aspects. In addition to developing and applying methods such as "participatory photography," to study how children's sense-making can be achieved through material–digital practices.

I will end this section with a warning. I want to stress that a widespread use of digital technologies and software in education that provide opportunities for cooperation, extending

only to co-option, not to co-creation, can hamper children's learning. This means that children should encounter technology in learning contexts that they have the opportunity to use to explore and which can be part of a creative process. I also want to note that teachers must thoughtfully relate to the material paradox of virtual realities in education. This means that we must consider in our teaching how tactile and haptic experience bridge the understanding from the material to the virtual.

6.3 Theoretical Implications

This study is of a qualitative nature and therefore its findings have some limitations in terms of general theories. However, I believe they are relevant in relation to educational theory. Thus, I have two main theoretical implications to offer, which I describe at the end of this section. During my work on this dissertation, I have found that the sense of touch remains underestimated in current educational theory and research. I suggest that tactile and haptic experiences may have a much greater impact on sense-making than is often assumed in education. Several concepts from the embodied cognition theory have been useful for developing knowledge of how explorative touch interaction with physical and virtual materialities can facilitate processes of sense-making. This study contributes to the already existing literature that supports the importance of children's arts and crafts education. In addition, it highlights explorative, tactile, and haptic perspectives in children's sense-making processes with digital technologies in education.

The importance of material interaction and exploration in young children's arts and crafts education has a long tradition in Norwegian ECE that goes all the way back to Fröbel in the eighteenth century (Pacini-Ketchabaw, 2017, p. 2). Gibson (1979) and Dewey's (1934/2005) theories offer an understanding of the experiences in human–material interaction, and these theories have been a foundation in ECE arts and crafts theory for a long time. Newer theories in the field of children's arts and crafts education stress the importance of how children develop experiential knowledge through material engagement from an early age (Carlsen, 2015, Fredriksen, 2011b; Pacini-Ketchabaw, 2017) and how material exploration is a way of negotiating meaning in accordance with the possibilities and limitations of the physical environments (Fredriksen, 2011a; Groth, 2017; Nordtømme, 2016). The meaning of material touch and materiality has been put on the agenda within different disciplines, including neuropsychology (Nicholas, 2010), educational science (Martinussen & Larsen, 2018), anthropology (Ingold, 2017), and the philosophy of science (Barad, 2007).

Initially I pointed to contemporary trends in education toward an instrumental approach to learning and a devaluation of experiential knowledge. The goal-oriented developments in education have been criticized by several educators and researchers (Biesta, 2018; Brunstad, 2015; Carlsen, 2015; Karseth & Ulstrup Engelsen, 2007; Otterstad, 2016). However, there are changes within Norwegian education that can be interpreted as positive. An example of this is how The Norwegian National Framework Plan for Kindergartens has emphasized that children are competent and active individuals who express themselves and learn through their bodies (MER, 2017). This promotes a holistic view of children's learning that, from my point of view, should always be at the forefront of the Norwegian ECE. I realize that this perspective is the opposite of the goal-oriented perspective. It is always a struggle to break from one paradigm and work to establish another. This is currently even more difficult because some influential policy makers have continued to support a view that takes the explorative out of education (Biesta, 2013, p. 1) and maintains an input–output logic to learning which is used to strictly control education (Brunstad, 2015; Brunstad & Olivierio, 2018). I think it is important to look back to the material and creative tradition in ECE. Arts and crafts education, and especially the haptic tradition of material exploration, which is characterized by open-ended processes, can be seen as a counterbalance to an instrumental approach to learning which might downplay children's experiential knowledge. I understand that children's sense-making through exploration might not fit into the models of effective "knowledge production" because the explorative process takes time, is not so controllable, and does not necessarily lead to measurable outcomes. However, the theory of how our minds are enacted in our interactions with the material environment (Noë, 2006, 2009; Shapiro, 2017) resonates well with and substantiates the idea that ECE arts and crafts education is where embodied experience through exploration and interactions with materials is essential in children's sense-making processes (Fredriksen, 2011b, Carlsen, 2015).

The theoretical framework of embodied cognition theory (Di Paolo & Thompson, 2017; Fugate, et al., 2018; Shapiro, 2017) and the findings from my study indicate that it is important to consider how touch perception and emotional and cognitive aspects relate to children's processes of sense-making in interaction with their environment, which can be both material and digital. I think that the theoretical framework of this study provides a solid basis for understanding both children's embodied minds and social aspects in their sense-making processes involving an exploration of their surroundings.

Based on the findings and theoretical implications of this study, I want to offer two recommendations. *First*, we as modern educators must acknowledge how tactile and haptic

experience bridges the understanding of the material to the virtual. The embodied cognition theory supports the importance of children's material exploration through to the digitalization of materiality. This perspective is important to underline in educational theory that addresses children's learning with digital technologies. *Second*, we must promote the explorative and emotional aspect of children's learning with digital technologies in educational theory. Newer theory on embodied cognition states how exploration is a central aspect of the intimacy of perception and action in experience (Michaels & Palatinus, 2017, p. 23) and how emotions are central in engaging with and making sense of the world (Maiese, 2017, p. 231).

6.4 Reflections on the Methodology of the Study

Here, I reflect upon the arts-based methodology of this study and describe how my research path has developed during this dissertation. In qualitative research, it is important to review the choices made through the research process and reflect upon them. This is part of making the research transparent and, in this case the study, and evaluating myself as a trustworthy researcher.

The theory of perception phenomenology (Merleau-Ponty, 1962/2005) was my foundation when I started working on this doctoral project. Gradually, through working with Cases 1 and 2, it became clear to me how to place the project within an embodied cognition theoretical framework. A good match between practice and theory was found in the embodied cognition theory. I understood how these theories largely confirmed the perception of phenomenology and how they would be helpful in developing deeper and more nuanced understanding of both individual and joint sense-making in interaction with different materialities, rather than relying on phenomenology alone.

When I started working on this dissertation, I began doing a *systematic review* of picturebook apps to determine how features in such technologies could contribute to sense-making. I made systematic searches in different databases and related these to the Preferred Reporting Items within the Systematic Reviews and Meta-analysis (PRISMA) process (Liberati, et al., 2009). During this search, I found some useful studies that were tangential to what I was searching for an answer to, but I could not go into depth or understand sense-making in interaction with a picturebook app using this approach. A next step was therefore to conduct a study of my own touch interaction with a virtual picturebook app to find its relationship to sense-making. My first consideration in studying my own interaction with the app was to take

a *phenomenological approach*. I considered this especially since I was familiar with using the phenomenology method because it has been a tradition in studying the making process using school methods within arts and crafts teacher education at my university for a long time (see Halvorsen, 2007). I also decided to use audio-visual documentation and make phenomenological descriptions of my experience interacting with the app. However, I found think-aloud accounts and diary questions as part of an arts-based approach to be more relevant for my study.

At an early stage in my planning, I considered doing *design-based research* (Barab & Squire, 2004). I knew that the focus in such studies is on the learners, their localities, and their communities. My idea was to collaborate with teachers in an ECE context to plan and implement a number of theory-based teaching interventions. However, as a first step in researching children's explorations of different materialities, I decided to tailor a case (Stake, 2010) and invite the children into exploration in a prearranged large-scale project room. The idea was to use my own knowledge as a/r/tographer working with materials and digital technologies in ECTE over many years to tailor a case to study children's exploration and sensory experience in such surroundings. The aim of tailoring the case was to examine children's touch interaction in material and digital surroundings and document what might otherwise be difficult to capture. I could have spent time mapping ECE's with a staff working with similar types of practice, and conducted a case in such a kindergarten; however, I chose to tailor the case to come closer to the scope of the target. Another argument for not choosing a design-based research approach was that it could have led toward a socially oriented direction between teachers and children, while my intention was to study sensory perception and especially the tactile and haptic experience in a social context.

The ABR methodology allowed me to use my own experience in developing understanding of sensory experience and sense-making. As Stake (2010, p. 62) has noted, "Understanding grows deep through experience." Using my senses and subjectivity in research was essential, but also proved challenging in relation to distancing my understanding from my own assumptions and preconceptions. Ahead of this study, I had an understanding that software and digital technologies are developed and largely used to achieve predefined learning outcomes and, to some extent, invite participants into exploration and creative processes. This stance was especially influenced by my practical experience as teacher but also from theoretical perspectives (Bølgan, 2018; Johansen, 2015; Nordkvelle et al., 2015). In exploring materialities together with children and teacher students, I was part of a shared experience, which had many positive aspects because I was close to and part of the experience and thus better able to

understand it. I sometimes think my experiences are richer when I take out my "researcher lens," as they become more vibrant because I am paying a certain kind of attention. What is important generally in such contexts is to not draw conclusions too quickly, but try to avoid possible misinterpretations as a result of one's own expectations, biases, prejudices, etc. Nevertheless, this study was never intended determine one ultimate truth, but rather to provide a personal, credible, and reflective contribution to realizing how involved students, children, teachers, and other can make sense exploring and interacting with different materialities.

The ABR methodology gave me the opportunity to examine sense-making in explorative touch interaction in different contexts. During the study, I turned my examination closer to studying touch, which required me to approach sensory experience to a greater extent than when I started the study. I needed methods that could help me develop an understanding of experiential knowledge. Based on this, I looked into sensory ethnography (Pink, 2015). Moreover, as an artist, researcher, and teacher, it was obvious for me to relate to a/r/tography (Irwin, et al., 2019) in this study. In Case 1, we were three a/r/tographers observing and interacting with students. When something relevant appeared in our joint exploration, we took photos. The choice of using observation as a method, and not audio-visual documentation, had a definite effect on my attention and presence during data collection. The study in Case 1 was dependent on our subjective experience and on our ability to remember interesting instances and to make detailed descriptions. This may be problematic in relation to the natural inaccuracies of memory. However, in this case, the photos were important, as they helped us to remember the selected instances in a more detailed way. In addition to our observations and photo documentation, we had access to the student's reports and photos. Another strength in this case was that there were three a/r/tographers that observed and could analyze the data in different ways. This was a form of data triangulation. However, we did not have the opportunity to go back and reexamine audio-visual data of important instances, which could have provided us with richer and more nuanced data.

When I was examining my own interaction with the picturebook app, I took advantage of think-aloud accounts (Bolger et al., 2003; Groth, 2017), video documentation, and diary questions (Groth, 2017). A strength in this study was that only I worked with the app, and there were no other factors that could interrupt my focus. One factor that needs to be noted in this context is that the think-aloud account has been criticized for influencing the experience and for its data being incomplete or irrelevant (Cross et al., 1996, as cited in Groth, 2017, p. 75). It might also be questionable whether a person is able to speak, experience, and reflect at the same time, and if the reflection in action (Schön, 1983) can only be an inner reflection. I experienced

the combination of the think-aloud account and video as valuable especially in capturing emotions, because this gave me the opportunity to observe my own non-verbal utterances, bodily movements, and bodily and facial expressions together with my think-aloud reflections during interaction. The combination of subject camera (camera attached to my body) and the overview camera that captured my entire body in the room also provided excellent opportunities to study the combination of my own verbal, facial, and bodily expressions. By responding to diary questions, I managed to capture some of *the immediate* in the sense-making process. It also provided me with verbal descriptions of my experiences.

Audio-visual empirical data proved to be important in Cases 2 and 3, but there were also limitations in what the video could capture. My own observations were valuable in this study. In Case 3, I considered inviting a third person to take photos and capture video. However, I decided that it was less disturbing for the children and me to use one headband camera on me, and one video camera in the corner of the room. This choice affected the angles of the video documentation and the quality of the visual material. When data are presented as thick descriptions and photo collages, many choices have been made in advance of presenting them. This kind of ABR presentation leaves interpretation open to the viewer or reader. This means that they can interpret the "findings" beyond my aim of the research, although some might say that this is a questionable way to present empirical data in a research context. However, I know that such data presentation can be effective in helping a viewer or reader to make sense of research findings. In the next section, I will present my suggestions for further research.

6.5 Suggestions for Further Research

This dissertation involves perspectives from many different fields, including arts and craft education, making disciplines, cognitive science, materiality studies, and learning with digital technologies. In this study, I have begun to uncover and develop knowledge that can be relevant to further research. Thus, I would suggest studying these four topics; 1) Sense-making through explorative touch interaction with haptic technology, 2) Material–digital practice involving children, artists, researchers, and ECTE and ECE teachers, 3) Further examination of digital technologies that provide opportunities for exploration and co-creation, and 4) Further investigating how audio–visual empirical data and artistic forms of exploration can deepen understanding of sense-making.

In this study, I have examined types of digital technologies that are currently available in Norwegian ECE and ECTE. *First*, I would recommend that sense-making aspects especially in the context of tactile and haptic perception be further examined within the context of newer technology such as haptic technology. This kind of technology can provide the user with haptic feedback such as vibration and more advanced gyroscopic movement, which might be more available in future ECE and ECTE. Arts and crafts education research involves in many ways an expertise related to children's sense-making processes in touch interaction with the material environment. Thus, I believe that arts and crafts educators are well positioned to lead the study of children's sense-making processes with haptic technology. In the course of my research, I have examined my own and others' sense-making of virtual materialities and gained invaluable insights into the material paradox of virtual realities. I think it would be worthwhile to study how children who have not experienced tactile and haptic perception of materials such as physical snow make sense of the virtual materiality of snow. Such a study will require methods to map the children's previous experiences with materials and to study specific qualities in sense-making with virtual materiality.

Second, I recommend that a material–digital explorative practice should be further developed and studied. Such a study would benefit from involving children, artists, researchers, and ECTE and ECE teachers. The focus could be to study additional ways teachers can facilitate sense-making through explorative touch interaction in material–digital practices. Sense-making strategies from this study could be used to tailor a case. I would also suggest considering the spatiotemporal potential in such a study. In this context, especially tactile and haptic exploration in a combination of materials and digital technologies could be the focus. I believe that such a study could be developed in the context of a makerspace or it could be influenced by makerspace pedagogy (see Burke & Crocker, 2019). It would also be important to do a study within a makerspace workshop and examine similar aspects of sense-making and materiality as in this study.

Third, I want to encourage further investigation of additional digital technologies that could provide opportunities for children's sense-making through exploration and co-creation. I think education could benefit from such a study. This would be a counterpoint to the tendencies of the efficiency and instrumental approaches to learning with digital technologies in education (Bølgan, 2018). Such a study would also be a counterpoint to the dominant view among many Western policy makers that focuses on quantitative and large-scale studies, which substantiates a disciplinary-oriented and one-dimensional understanding of children's learning with digital technology (Kucirkova et al., 2019, p. 3). *Last*, I would recommend continuing to develop ABR

methods that can develop understanding of embodied and experiential knowledge in the context of digitalization of materiality. ABR can produce valuable data in the context of studying children's sense-making process in interaction with digital technologies. I share this belief with Knight (2019). In addition, there is a need for researchers to use innovative and creative methods to allow for more complex and nuanced data in the context of digitalization in education. There are many obvious crossovers among the senses, sensory ethnography, and an arts-based creative practice. Personally, I have a desire to continue my investigation of how audio-visual empirical data and artistic forms of exploration can deepen understanding of sense-making.

6.6 Summary of the Discussion

The objective of this study was to examine how explorative touch interactions with physical and virtual materialities can facilitate processes of sense-making. This has been examined through three different case studies. Theory of embodied cognition, which explains how our minds are enacted through our bodies, has been useful in developing understanding of sense-making in exploration of different materialities. The findings from the study are discussed through six main identified themes. The *first* theme relates to how tactile and haptic dimensions of materiality bridge understanding of the material to the virtual. A person's sensory experience of the material world needs to be immersed in a virtual world to make sense of virtual materiality. I found that children use similar strategies to explore both physical and virtual materialities, although these materialities have different properties. The *second* theme involves the idea that emotions and imagination are embodied sense-making faculties at work during interaction with virtual materialities. Emotions and imagination of past perception are crucial in making sense of virtual materiality. The *third* theme touches on how virtual materiality can initiate new discoveries and shape the experience of the material world. Digital technologies can, through interaction, shape the experience of something familiar like a physical material, and expand beyond a person's sensory capacities and make different experiences and discoveries than the material world alone can offer. Thus, by using digital technologies in exploration, children can experience other qualities of materiality than the material can offer alone. The *fourth* theme outlines the idea that digital technologies and strategies that provide opportunities for co-creation and exploration are essential to sense-making. Children's combination of physical materials and digital technologies can provide them with opportunities

to be explorative and co-creative. Different strategies and potentials for combining physical and virtual materialities in sense-making were identified through the study. Elementary digital technologies, such as a camera app or a projector, can create opportunities for being explorative and co-creative. However, it must be noted that, in this study, while the innovative use of the software of the virtual reality picturebook app created only potential to be co-opted, there was not an opportunity to be co-creative. This could be improved in the future. The *fifth* theme points out how joint exploration influenced the process of sense-making with digital technologies in interaction with the physical environment. Interactions between students, between children, between children and adults, and between students and teachers were important to sense-making with materials and digital technologies. The *sixth* theme relates to how haptic visuality and artistic forms of exploration can deepen understanding of sense-making and touch interaction. Haptic visuality was found to be especially relevant to developing knowledge in this area. Audio-visual empirical data and reflection through collage making were also found to be valuable in developing understanding of sense-making and touch.

Thus, I contend that this study has practical implications for ECE and ECTE in the context of facilitating sense-making. These implications are discussed in four identified themes. The *first* acknowledges that physical materials and manual technologies are needed in education. The *second* identifies that it is essential that teachers apply digital technologies and strategies that invite others into joint exploration and co-creation to facilitate sense-making. However, a widespread use of digital technologies and software in education that provide opportunities for cooperation extending only to co-option, not to co-creation, can unfortunately result in hamper children's learning. This means that children should encounter technology in learning contexts that they have the opportunity to use to explore and which can be part of a creative process. Teachers must thoughtfully relate to the material paradox of virtual realities in education. This means that they must take into consideration in teaching how tactile and haptic experience bridge the understanding from the material to the virtual. The *third* states that it is important that teachers in both ECE and ECTE develop a material–digital explorative practice. The *fourth* emphasizes that it is important to continue to develop and apply arts-based methods that can contribute to understanding sensory experience in interaction with digital technologies. In addition, I believe that this study has *two theoretical* implications, which are important for education. *First*, tactile and haptic experience bridges the understanding from the material to the virtual in educational theory, and *second*, it is imperative to further investigate the explorative and emotional aspects of children's learning with digital technologies in educational theory.

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8 Original Publications

8.1 Publication I

8.1.1 Eksperimentelle utforskinger av materialer og materialitet i transmaterielle landskaper (Original Version)

8.1.2 Experimental explorations of materials and materiality in transmaterial landscapes (Translated Version)

8.2 Publication II: Sense-making through touch interaction with a picturebook app

8.3 Publication III: Children's sense-making through exploration: Grasping physical and virtual materialities

8.4 Publication IV: Making sense of movement: A/r/tographic explorations of physical and virtual environments

Publication I (Original Version)

Eksperimentelle utforskinger av materialer og materialitet i transmaterielle landskaper

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Eksperimentelle utforskinger av materialer og materialitet i transmaterielle landskaper

Sammendrag

Artikkelen bygger på et forskningsprosjekt forankret i en formingsfaglig undervisningskontekst i barnehagelærerutdanninga. Gjennom en A/r/tografisk tilnærming undersøkes det hva som skjer når det åpnes for eksperimentelle, rhizomatiske og uforutsette prosesser som transformerer fysiske og digitale materialer og fenomener i skapende handlinger. Rammeplan for barnehagen fra 2017 forutsetter en fornyet digital praksis i barnehagen og i barnehagelærerutdanninga. Gjennom koblinger av materialer og digitale transformasjoner oppstår nye materielle uttrykk, og nye handlingsmuligheter i skapende prosesser produseres. I artikkelen vises det videre til hvordan skapende prosesser i et kollektivt læringsmiljø kan akkumulere mer kunnskap gjennom delt kunnskap ut fra en rhizomatisk forståelse av kunnskapsprosesser.

Nøkkelord: A/r/tografi, eksperimentelle prosesser, embodied, rhizome, transmaterialitet og digital praksis.

Innledning

De empiriske undersøkelsene i denne artikkelen inviterer inn i et undervisningsprosjekt sammen med forfatterne og barnehagelærerstudenter ved Universitetet i Sørøst-Norge, USN. Som resten av samfunnet preges barnehagen av rask teknologisk utvikling. Rammeplanen for barnehagen (KD, 2017, s. 16–17) legger klare føringer for barnehagens digitale praksis, og gir barnehagelæreren tolknings- og handlingsrom til å være med på å forme denne praksisen. Det krever utvidet kunnskap om og forståelse for digitale potensialer hos barnehagelærere.

Artikkelen setter fokus på erfaringer med å etablere forbindelser mellom eksperimenterende og skapende prosesser med materialer og barnehagens digitale praksis. Gjennom ulike empiriske utsnitt, teoretiske og metodiske innfallsvinkler fokuserer vi på utforskende prosesser. Vi løfter frem den formingsfaglige tradisjonen i barnehagen og styrker studentenes utforskende og skapende kunnskaper for en digital barnehagehverdag. Formingstradisjonen bygger på at barns direkte erfaringer med materialer og verktøy er grunnleggende for læring (Dewey, 1934/2005). Barn utforsker materialer med hele kroppen og forholder seg sanselig til verden (Carlsen, 2015; Eisner, 2002; Fredriksen, 2011, 2013; Waterhouse, 2013). Esther Thelen underbygger i en oversiktsartikkel (Thelen, 2000) hvordan barns aktive fysiske handlinger i omgivelsene er med på å forme hjernen. På bakgrunn av denne kunnskapen vet vi nå at all læring er fysisk kroppslig forankret; den er *embodied* (Bengtsson, 2013; Gulliksen 2017; Moser, 2014). Med utgangspunkt i formingstradisjonens vekt på kroppslige og affektive handlinger med fysiske to- og tredimensjonale materialer, er det bekymringsfullt at denne ser ut til å være svakere forankret i dagens barnehage enn for få år siden (Carlsen, 2015; Østrem m.fl., 2009).

Vi tar opp utfordringen som ligger i rammeplanens fokus på digital praksis og løfter samtidig fram betydningen av kroppslig læring i konkrete møter med fysiske materialer. I undervisningsprosjektet utfordrer vi barnehagelærerstudenter til selv å undersøke og skape i materiale og digitale kontekster. Nye forbindelser mellom det fysisk tilstedeværende, og det digitalt

blivende, *becoming* (Deleuze & Guattari, 1987) innlemmes i deres kunnskaper som ansvarlige for barnehagens leke- og læringsmiljø. Dette omhandler det Donna Haraway (2012) definerer som «a praxis of care and response – *response-ability*» (s. 302). En etisk praksis som omhandler ansvar, handling og respons som vever sammen materialiteter og språk i «worldly practices» (Haraway, 1999, s. 109). Karen Barad (2012) følger opp tenkningen rundt response-ability ved å legge til at det ikke handler om korrekt respons, «but rather a matter of inviting, welcoming, and enabling the response of the Other» (s. 81). I vårt sammenvevde undervisnings- og forskningsprosjekt handler det om slike etiske og skapende kollektive praksiser hvor det undersøkende, skapende og lærende sammenfiltres.

Becoming kan best oversettes til *blivelse* og henspeiler på noe som er i prosess og i bevegelse. Blivelse kan sees som en drivkraft som lar noe skje. Ifølge Deleuze og Guattari kan ikke blivelser forstås som noe lineært med et startpunkt og et sluttpunkt, men som noe som er i mellomrom, som omslutter og bølger mellom, gjennom, frem og tilbake. Vi er innfiltret i blivelser gjennom våre utforskende formingsprosesser i ulike materialer og materialiteter. Dette fordrer, slik vi forstår det, en åpenhet for det som kan komme, det som oppstår i mellomrommene og for det uforutsette.

Digital teknologi er integrert i undervisningsprosjektet både som verktøy og som medium i undersøkelsene. Studenter og lærere har arbeidet eksperimentelt og skapende med fysiske materialer og digital utforsking med nettbrett, projektor, lyskilder, smarttelefoner og linser (makro, vidvinkel og fish eye) som kan brukes på smarttelefon og nettbrett.

Det sentrale forskningsspørsmålet i prosjektet er: *Hva skjer når vi åpner for eksperimentelle og uforutsette prosesser som transformerer fysiske og digitale materialer og fenomener i skapende handlinger?* Vi belyser ulike aspekter ved dette spørsmålet gjennom empiriske utsnitt som kan leses som hendelser, oppdagelser eller små narrativer (Waterhouse, 2016) fra undervisnings-prosjektet. Videre diskuterer vi samhandlinger mellom studenter, lærere, materialer og verktøy, og argumenterer for en ny skapende material-digital praksis i barnehagen der ulike uttrykksformer inngår i det vi kaller *transmaterielle* (Munster, 2014) landskaper.

Ny rammeplan, nye perspektiver

Flere forskere viser at det arbeides mindre med de estetiske fagene i barnehagen enn før (Bamford, 2012; Carlsen, 2015; Halland & Vist, 2016; Østrem et al., 2009). Dette er en tendens som også gjenkjennes i barnehagelærerutdanninga ifølge rapport fra Følgjegruppa for barnehage-lærerutdanning (2016). Mindre fokus på estetiske fag i barnehagen og barnehagelærerutdanninga indikerer et endret syn på hva barnehagens faglige og pedagogiske innhold skal være, og vi ser samtidig et økt press på målstyrt læring (Carlsen, 2015; Otterstad, 2016). Tross rammeplanens vekt på utforskende, kreativ og skapende bruk av digitale verktøy, viser forskning at det er relativt lite utforskende bruk av digital teknologi i skapende virksomhet i barnehagen (Bølgan, 2009; Letnes, 2014). Dette underbygges av den nasjonale kartleggingsundersøkelsen *Barnehagemonitor 2015 – den digitale tilstanden i barnehagen* gjennomført av nasjonalt senter for IKT i utdanningen (Jacobsen, Kofoed & Loi, 2015). Ifølge undersøkelsen ser man en generell økning i barns bruk av digitale verktøy særlig knyttet til å lytte til musikk, ta bilder og spille spill. Undersøkelsen konkluderer med at barn ser ut til å primært delta i aktiviteter av konsumerende karakter og mindre i aktiviteter som gir rom for å være skapende. Det er derfor et behov for en fornyet digital praksis i barnehagen, og dette får konsekvenser for barnehagelærerutdanninga. Formingsfaget har et særlig ansvar for visuell kompetanse i hele utdanningsløpet fra barnehage til høyere utdanning. En fornyet digital praksis må forholde seg aktivt både til visuelle uttrykksformer og dessuten inkludere romlig skapende virksomhet i arbeid med digitale uttrykk.

Rammeplanen fra 2017 legger føringer for barnehagens digitale praksis. Den tydeligste endringen fra forrige rammeplan (KD, 2011) er formuleringen fra *bør* til *skal* (KD, 2017) knyttet til barnas og personalets bruk av digitale verktøy og uttrykksformer: «Personalet skal legge til rette for at barn utforsker, leker, lærer og selv skaper noe gjennom digitale uttrykksformer» og «skal utforske kreativ og skapende bruk av digitale verktøy sammen med barna» (KD, 2017, s. 16–17). Det fordrer at barnehagelærerne utvikler kunnskap om digitale verktøy og uttrykk både som forberedelse til kreative prosesser og gjennom utforskende og kreative prosesser sammen med barn. Rammeplanen peker altså mot en fornyet digital praksis som utvikles i kollektive prosesser. Under fagområdet Kunst, kultur og kreativitet står det at barnehagen skal bidra til at barna: «møter et mangfold av kunstneriske og kulturelle uttrykksformer», og «bruker ulike teknikker, materialer, verktøy og teknologi til å uttrykke seg estetisk» (KD, 2017, s. 51). «Barnehagen skal bidra til at barn har tilgang til ting, *rom* og *materialer* som støtter opp om deres lekende og estetiske uttrykksformer» (KD, 2017, s. 19, vår kursivering). Dette underbygger det eksperimentelle og utforskende aspektet som vi kan finne i barns lek og estetiske uttrykk. En endring fra *bør* til *skal* kan sees som en konsekvens av tidligere diskusjoner om forskyving av barns posisjon fra konsument til produsent i digitale sammenhenger (Waterhouse, 2013; Letnes, 2014; Haug & Jamissen, 2015).

Barnehagelærerutdanning, nye perspektiver og ny praksis

Barnehagepersonalet skal legge til rette for at barn utforsker, og de skal selv utforske sammen med barn på en kreativ og skapende måte. Undervisningsprosjektet som danner grunnlag for denne artikkelen er gjennomført i barnehagelærerutdanningens fordypningsemne *Material og digital utforsking, erfaring og kunnskap i barns formingsprosesser* ved USN. Emnet er utviklet for å ivareta og skape møtepunkter mellom formingsfagets materialerfaringer og utforskende tradisjon, og digitale verktøy og uttrykk i skapende kontekster. Prosjektet er ikke avsluttet, men går inn i nye faser for hvert studentkull. Det har som målsetting å utvikle forskningsbasert undervisning og samtidig drive undervisningsbasert forskning tett på vår egen praksis som lærere i samhandling med studentene, og i senere faser med barn og personale i barnehagen.

Studentenes pedagogiske og didaktiske kunnskaper er knyttet til deres kroppslige erfaringer. De teoretiske inngangene som beskrives i det videre underbygger dette synspunktet og peker på forståelser av materialiteter, teknologier, relasjoner, kropp og kunnskap, og på det eksperimentelle og uforutsette i skapende prosesser.

Teoretiske innganger

Antropologen Tim Ingold sier at: «Like all other creatures, human beings do not exist on the 'other side' of materiality but swim in an ocean of materials» (Ingold, 2007, s. 7). Verden består av materie. Materien inngår i skapende prosesser i form av materialer. Det er økende vitenskapelig støtte for at kognisjon sees i sammenheng med kroppers samhandling og relasjoner med det fysiske miljøet i læringsprosesser (Thelen, 2000; Bengtsson, 2013; Moser; 2014). Vi legger til grunn at læring er *embodied*, forankret i kroppslig handling, der sansing, persepsjon og erfaringer er en del av vår kognisjon. Dette læringssynet bygger opp under kroppslige og undersøkende handlinger med materialer og verktøy i utforskende og skapende prosesser. "In order to understand cognitive processes we must understand them as features of the whole body (including the brain) and its relations with the environment (i.e., the body embedded in a given environment, the body using different tools in a given environment)" (Raja, Biener & Chemero, 2017, s. 147). Kroppen som integrert del i et gitt miljø, med tett relasjon til materialer og verktøy, er en forutsetning for læring.

Psykologen James J. Gibson introduserte begrepet *affordance* for å beskrive levende organismers forhold til omgivelsene og hvilke handlingsmuligheter (affordances) omgivelsene tilbyr (Gibson, 1979). En organisme samvirker med sine omgivelser ved at persepsjonen av

omgivelsenes affordances knyttes til handling, og kognisjon eller læring kobles direkte til de handlingsmulighetene omgivelsene tilbyr» (Carlsen, 2015, s. 132). Det er vesentlig for læring knyttet til materialer og teknologi i formingsprosesser å oppdage hvilke «handlingspotensialer» (Waterhouse, 2013, s. 32) og uttrykk materialer og teknologier kan produsere. Det handler om meningsfylte og virkningsfulle forbindelser som kan materialisere seg i kunstneriske uttrykk.

Vår kunnskap er avhengig av den konteksten den utvikles i, den er situert (Haraway, 1988). Kunnskap blir til i en bestemt situasjon, i tid og i relasjon til sted. Om materialene og tingene opptrer i en annen kontekst, blir læringsprosessene annerledes (Waterhouse, 2013). Rommet er en del av konteksten og er fylt av begrensninger og muligheter, og er innen Reggio-Emilas pedagogiske filosofi definert som en tredje pedagog, en medspiller i læringsprosesser (Carlsen, 2015). «Rommets språk er svært sterkt og en betingende faktor. Selv om koden ikke alltid er eksplisitt og gjenkjennelig, oppfatter og tolker vi den fra svært ung alder. Som alle andre språk påvirker derfor også det fysiske rommet tankens dannelse» (Rinaldi, 2009, s. 91). Hege Hansson sier at «barnehagens rom er et fleksibelt medium og et tredimensjonalt lerret, som kontinuerlig kan manipuleres og endres» (Hansson, 2016, s. 18).

Å se materialer, ting og teknologier som virksomme kan åpne for nysgjerrighet og mottakelighet for det som skjer, det som oppdages og det uforutsette (Häikiö, 2017). Å lære i utforskende og eksperimentelle skapende prosesser krever en vekselvirkning mellom innhold, drivkraft og samspill.

Om rhizomer og intra-aksjoner i eksperimentelle og undersøkende praksiser

Eksperimentelle og undersøkende metoder i skapende virksomhet er innganger og arbeidsmåter for å oppdage flere uttrykksmuligheter i relasjon til materialer og materialitet. Tingene undersøkes på nye måter, og en eksperimentell praksis åpner rom av uendelige potensialiteter ifølge Welsch (1995, i Blume, 2015). Eksperimentelle prosesser krever iderikdom, spekulasjon og drivkraft, og prosessen drives av en kontinuerlig veksling i og gjennom observasjon og handling. Eksperimentelle prosesser søker noe som ikke er klart definert på forhånd, men som blir til gjennom handlinger. Dette fordrer åpenhet for det uforutsette og for at prosesser innehar intuitive elementer (Blume, 2015). Det handler om å la tilfeldigheter få kraft. Slike prosesser kan sees som *assemblager* av ting, ideer og strukturer som beveger seg som bølger og som kan skape nye forbindelser, blivelser, og muliggjør produksjon av ny kunnskap og nye innsikter.

En slik *rhizomatisk* prosess er ikke lineær, men skyter i ulike retninger, kobler hendelser og fenomener sammen på ulike måter, den omformer og omdanner. Begrepet *rhizom* er hentet fra botanikken, og er utviklet som et filosofisk konsept hos Deleuze og Guattari (1987), og er anvendt i nyere barnehageforskning og pedagogisk litteratur. Begrepet viser til en type rotsystem der planten ikke har en hovedrot, men et nettverk av røtter som skyter stadig nye rotskudd i ulike retninger, de krysser hverandre og ligger gjerne tett som en vev eller et teppe under jordoverflaten. Eksempler på norske planter som vokser rhizomatisk, er dauvneslerot (bilde 1), hvitveis, nesle, sisselrot og skvallerkål. I en skapende eksperimentell læringsprosess kan det rhizomatiske gi mange åpninger, potensialer og uante muligheter eller «lines of flight» (Deleuze & Guattari, 1987) som kan forfølges gjennom åpne og eksperimentelle tilnærminger (Olsson, 2014).

Kollektive estetiske læreprosesser kan også åpne for forsterket læring gjennom det Szatkowski omtaler som *den estetiske fordobling* (se Austring & Sørensen, 2006, s. 172). Det betyr at kunnskapen som produseres i kollektivet er akkumulativ, noe som fører til at gruppas samlede kunnskap vokser raskere enn om den enkelte hadde gjennomgått læreprosesser utenfor kollektivet. Fordoblingen ligger i at kollektivets deltagere supplerer og komplementerer hverandres utforskinger. Kunnskap og innsikter utvikles og deles i stadig veksling. Vi velger å se dette, ikke bare som fordobling, men som *forflering*.

Bilde 1. Dauvneslerot. E. Korsmos ugressplansjer. Utstilt i Botanisk hage, Oslo.

I formingsfaglig sammenheng er det ikke utelukkende den enkelte og de andre personene i et lærende kollektiv som står i utveksling med hverandre. Det fysiske miljøet, materialene og de verktøyene som er en del av situasjon, som utgjør et *assemblage* (Deleuze & Guattari, 1987), har avgjørende betydning for hvilke prosesser som kan foregå. En leksikalsk definisjon av assemblage viser til et «kunstverk som er satt sammen av forskjellige materialer; også betegnelse på en teknikk, opprinnelig en tredimensjonal utgave av collage» (Assemblage: kunst, 2018).

Assemblage som et filosofisk konsept er knyttet til Deleuze og Guattaris prosessontologi og kommer av det franske ordet *agencement, ...* «a term that refers to the action of matching or fitting together a set of components (agencer), as well as to the result of such an action: an ensamble of parts that mesh together well» (Delanda, 2016, s. 1). «Nor are assemblages exactly things. They are also processes of perpetual self-construction. The French *agencement*, translated as «assemblage», can mean both an arrangement of things and the act of arranging those things. An *agencement* thus is not just an assemblage of things, but also a process of «agencing», just as a circuit of de-siring-machines is a «machining» of machines, an active bringing-into-existence of its own circuitry» (Bogue, 2007, s. 145). Et assemblage kan dermed forstås som et arrangement av ulike enheter (materialer, gjenstander, kropper), og virkningen av koblinger og utvekslinger som oppstår som effekter av sammenkoblinger mellom enheter i et assemblage.

Estetisk *forflering* kan også sees som et *intra-aktivt fenomen* (Barad, 2007) som ikke bare innlemmer mennesker, men også ikke-menneskelige aktører i den kollektive, meningsskapende prosessen. Perspektivet flyttes fra inter-aktive relasjoner til intra-aktive fenomener som omfatter

både levende og ikke-levende aktører i omgivelsene i en gitt situasjon. I et intra-aktivt fenomen operer ulike identiteter i en felles prosess, der det skapes både mening og form (Barad, 2008; Carlsen, 2015). Med dette perspektivet forskyves og fordeles makten fra mennesket som ensidig handlende sentrum i prosessen, til det vibrerende og aktive mellomrommet mellom mennesker, ting og materialer som er virksomme i prosessen, i assemblagen. I barnehagen kan dette bety at det er mulig å forstå sanden i sandkassa, leira, byggeklossene og bolledeigen som aktive medspillere sammen med barna i formende prosesser. På samme måten er studentenes utforsking for eksempel av den tørka purreløkblomsten (se bilde 5 og 6) og utvekslinger av kunnskap helt avhengig av samspillet med verktøy som nettbrett, smarttelefon og projektor. Fysiske materialer sammen med digitale verktøy og applikasjoner de har til rådighet gir retning for hva som er mulig å undersøke i konteksten. Samtidig er det åpent hvilke uttrykk og hvilke kunnskaper som produseres underveis.

Teknologier, verktøy og embodiment

«No object considered purely in and for itself, in terms of its intrinsic attributes alone can be a tool. To describe a thing as a tool is to place it in relation to other things within a field of activity in which it can exert a certain effect» (Ingold, 2011, s. 56). Ifølge Ingold er verktøy ting som blir virksomme som verktøy gjennom handling og i relasjon til det handlende og det materialet det handles i. En sag blir først virksom som verktøy når noen sager med den i et stykke tre. Å definere ting som verktøy er å knytte dem til handling. Gjennom å bruke verktøy er vi ikke bare handlende i verden, men også i en prosess for å forstå verden (Ingold, 2011). Teknologi knyttes i hovedsak til den menneskeskapte verden, selv om enkelte dyrearter også bruker verktøy. Verktøybruk står imidlertid i relasjon til den ikke-menneskeskapte verden, til natur, materie og fenomener. Opp gjennom historien har mennesket utviklet og tatt i bruk ulike teknologier, som verktøy, maskiner og andre teknologiske oppfinnelser i hverdagsliv og skapende handlinger. Teknologi omhandler alt fra enkelt håndverktøy som kniver og malepensler til avansert teknologi som roboter. «A tool is a sort of extension of the hand, almost an attachment to it or a part of the user`s own body» (Gibson, 1986, s. 41). Verktøy er i relasjon til kropp i handling (Ingold, 2011). Digitale teknologier som nettbrett og smarttelefoner er i intra-aksjon med kropper, materialer og omgivelser. Utviklingen av digitale teknologier innebærer forandring i relasjoner mellom mennesker og maskiner. Dette betegnes som «human computer interaction» (Farr, Price and Jewitt, 2012). Teknologiens potensialer i håndgripelige digitale mobile enheter med berøringsteknologi (multi-touch) gir muligheter til å utforske et bredt spekter av persepsjonsbaserte handlinger (Farr, Price & Jewitt, 2012).

Materialer, materialitet og transmaterialitet

Ifølge Ingold er ikke materialitet håndgripelig på samme måte som materie og materialer. Å definere materialitet er derfor ingen enkel øvelse.

> I can touch the rock, whether of a cave wall or of the ground underfoot, and can thereby gain a feel for what rock is like as a material. But I cannot touch the Materiality of the rock. The surface of materiality, in short, is an illusion. (Ingold, 2007 s. 7)

Ingold (2007) sier at materialitet er en illusjon, men hva betyr det? I dagligtale kan vi si at noe materialiserer seg, tar form og blir synlig for oss. Solveig Nordtømme tar i sin doktorgradsavhandling for seg barns lek med rom og materialitet og skriver at «materialitet blir, i denne studien (hennes undersøkelse), brukt som en fellesbetegnelse for ting og materialer (Nordtømme, 2016, s. 1), men er det det som er materialitet? Det er jo både konkret og håndgripelig i motsetning til Ingolds forståelse av materialitet som illusjon. Materialitet har med materie og materialer og gjøre, men det er *mer* enn tingene og materialene vi omgir oss med. Materialitet kan

sees som et intra-aktivt fenomen, og et performativt fenomen (Barad, 2007). Det er noe som både er og gjør. Materialitet er virkninger og effekter av relasjoner. Slik sett er det ikke håndgripelig og kan sees som illusjoner i tråd med Ingolds definisjon, men det er også relasjoner til noe konkret og håndgripelig slik Nordtømme bruker begrepet. Sammenhengen mellom mennesker og materie/materialer slik vi ser det kan betegnes som et intra-aktivt forhold i gjensidig påvirkning mellom mennesker og materie/materialer. Mening og form skapes i et aktivt mellomrom mellom materie/materialer og mennesker i handling (Carlsen, 2015; Lenz Taguchi, 2010), og materialitet blir slik vi anvender det i denne sammenhengen relasjoner mellom mennesker og materialer og de virkninger som oppstår i handlinger i de intra-aktive relasjonene.

Materialer som sand, plast, tekstiler, papir og vann er materialer som har substans som kan tas på og endres manuelt. De er materialer med fysiske egenskaper som konsistens, tekstur og farge. Noen materialer er tett knyttet til natur slik som leire, tre og sand, mens andre er prosesserte materialer som allerede er i en transformasjonsprosess. Plast er et slikt materiale som har sin opprinnelse i råolje, og gjennom bearbeiding kan ende opp som cellofan og plastposer. Kunnskap om materialer i produksjonsprosesser, i «material flow» (Ingold, 2007), gir innsikter i materialenes egenskaper, deres motstand og muligheter, deres affordancer (Carlsen, 2015; Fredriksen, 2011, Waterhouse, 2013). Materialiteter som lys, skygge, bevegelse, lysbrytning og grader av transparens eksempelvis opplevd gjennom kameralinsa, er fenomener som kan virke som materialer. De kan inngå som elementer i å skape kunstneriske uttrykk. Fenomenene er flyktige og uhåndgripelige, men likevel mulige å bearbeide og anvende som materielle elementer i skapende prosesser (Waterhouse, 2013).

Digital materialitet (Leonardi, 2010) gjøres tilgjengelig gjennom teknologiske enheter, eller transformeres gjennom printing til to- eller tredimensjonale uttrykk eller ting. Digital materialitet har andre egenskaper enn fysiske materialer og er uavhengige av betingelser som fysiske materialer har, som for eksempel tyngdekraften. Opplevelse av digital materialitet er en sammensmelting av det visuelle, det auditive og det fysiske materialet f.eks. ved henders berøring av nettbrettet. Digital materialitet i formingsprosesser kan være uttrykk produsert med eksempelvis video og foto, som integreres som materielle komponenter i rommet sammen med andre typer fenomener og materie/materialer. Fysisk materie og fenomener transporteres gjennom digitale verktøy og transformeres i rommet i møte med ulike flater og teksturer i omgivelsene. *Transmaterielle* uttrykk (Munster, 2014) oppstår når ulike fysiske materialer og materialiteter, og digital materialitet (Leonardi, 2010) innfiltres i hverandre. Transmaterialitet kan forstås som «matter in movement, matter as relations of forces, matter as an energetics» (Munster, 2014, s. 158). Transmaterialitet er materie/materialer i transformasjon, ikke i form, men fra fysisk materie/materiale til signaler og koder bearbeidet gjennom digitale enheter. Materie/materialer som både transporteres og transformeres i tid og rom.

Ingold (2013) sier at; «in the art of inquiry, the conduct of thought goes along with, and continually answers to, the flux and flows of the materials with which we work. These materials think in us, as we think through them» (s. 6). Gjennom skapende prosesser åpner vi oss for å følge og handle med materie og materialer i endring gjennom transformasjoner og materialers flyt eller «material flow» som Ingold sier (2013). Gjennom slike prosesser åpnes det for at kunnskap utveksles i intra-aksjoner mellom mennesker, materie, materialer og teknologi. «To describe the properties of materials is to tell the stories of what happens to them as they flow, mix and mutate» (Ingold, 2007, s. 14).

Metodiske innganger

Gjennom deltagende observasjon og kollektive utforskinger i prosjektrommet kommer vi som lærere, utøvere og forskere tett på studentenes undersøkelser. Gjennom eksperimenteringer i

prosjektrommet utvikles innsikter og relasjoner knyttet til materialer og fenomener og hvordan disse gjensidig påvirker hverandre. Personlige erfaringer er en viktig tilgang til kunnskap i kvalitativ forskning av eksperimentell karakter (Stake, 2010; Bresler, 2006).

I undervisning og veiledning utforsker vi sammen med studentene, og vi posisjonerer oss som *a/r/tografer* (Irwin & Springgay 2008).

> A/r/tography as practice-based research is situated in the in-between, where theory-as-practice-as-process-as-complication intentionally unsettles perception and knowing through living inquery. (Irwin & Springgay, 2008, s. xxi)

A/r/tography er et engelsk begrep som ikke kan oversettes til norsk uten å miste mye av sin betydning. A/r/tography er en praktisk basert forskningsmetodologi innenfor kunstbasert forskning, ABR (arts-based research methodology) (Barone & Eisner, 2012; Rolling, 2010). Gjennom denne metodologien veves kunst (det skapende), forskning (det undersøkende) og undervisning (læring) sammen gjennom forskeren som både er kunstner (A/rtist), forsker (R/esearcher) og lærer (T/eacher). Det skapende og det skrivende utfyller hverandre i undersøkelsen, «it is a process of double imaging that includes the creation of art and words that are not separate or illustrative of each other but instead, are interconnected and woven through each other to create additional meanings» (Springgay, Irwin & Kind, 2005, s. 899).

A/r/tography er en forskningsmetodologi som utfører, bukter og tvinner seg som et rhizome (Irwin & Springgay, 2008). En metodologi som er åpen og uforutsigbar og som drives frem av skapende prosesser som forgreiner seg i stadige blivelser. «There are no points or positions in a rhizome, such as those found in a structure, tree, or root. There are only lines» (Deluze & Guattari, 1987, s. 8). Linjer som krysser, tangerer, beveger og bukter seg.

Kunstneriske og skapende prosesser kan forstås som måter å undersøke verden på, som «worldly practices» (Haraway & Goodeve, 1999), og gjennom kunstnerisk virksomhet kan ny kunnskap produseres i utveksling mellom menneskelige og ikke-menneskelige enheter i skapende intra-aktive prosesser (Barad, 2007).

«Learning/creating/inquiring in, from, though, and with situations occurs in the in-between spaces – those spaces that make connections that are often unanticipated» (Irwin et al, 2006, s. 72). Gjennom forskerposisjonens tre identiteter A/R/T (Irwin et al, 2006), som både er sammenfiltrede, forskjellige og tangerende, får vi som forskere innsikter i undervisningskontekster og læringsprosesser gjennom felles utforsking, læring og refleksjon sammen med studentene som også er skapende, lærende og undersøkende. Vi undersøker muligheter og potensialer i mellomrom som utspiller seg mellom mennesker og det ikke-menneskelige, det skapende, det undersøkende og det lærende.

Vi gjør utsnitt og beskrivelser av hendelser i prosjektrommet for å vise til deler av det empiriske materialet som er virksomt i denne artikkelen og i våre retrospektive refleksjoner. Beskrivelsene er et grep for å gjenskape noe av opplevelsen fra prosjektrommet for leseren. Det empiriske grunnlaget for artikkelen er i sin helhet våre forberedelser til undervisning, egne observasjoner, fotografier, undervisningens dokumenterte forløp og kollektive utforskinger, studenters utsagn, prosesser og uttrykk, fotografier og video.

Scener fra et prosjektrom

> Vi er spente. I mange dager har vi jobbet for å forberede oss og det store prosjektrommet for studenters utforsking av det vi kaller materiale og digitale landskaper. Vi er spente fordi vi ikke helt kan vite hva som kommer til å skje når studentene går inn i rommet. Rommet er ryddet. Hvite podier er plassert på gulvet og skaper små platåer hvor materialer er lagt frem og arrangert i assemblager

(se bilde 2 og 3). Kari låner bort skatter som er samlet over år. Her finnes tørket rødkål og skiver av tørket appelsin, kongler, purreløkblomster, bark, svamp, frø, tørket løv, steiner, sand, siv og trebiter. Et arrangement av organiske ting og materialer med ulike kvaliteter og lukter ... Vi har også funnet frem papp, papir, glass, speil, cellofan, netting, tekstiler, speil og glassboller. Et arsenal av materialer med ulik grad av gjennomskinnelige. Her er trepinner, plastrør, papprør, staver av pleksiglass og mye mer … Vi kjenner det sitrer i kropper. Dette vil vi sette fingrene i! Kjenne, løfte, stryke og … snuse inn lukter. Skjøre kvaliteter i tørkede kålblader og lettheten i konglefrø fascinerer. Florlette vevde tekstiler og et lite rede som en fugl iherdig og systematisk har flettet sammen. Materialene og tingene inviterer på ulike måter. Hva skjer når studentene slipper til? Vil de kjenne på, stryke og utforske? Vil noen knuse et tørket blad mellom fingrene og frydes over lyden som skapes? Vil noen løfte opp et speil, holde det opp mot lyset, beveger det fram og tilbake og se hvordan lyset brytes og reflekteres i materialet? Vil de kjenne på begjær etter materialer? … Snart slippes studentene inn for å utforske materialer og transformasjoner i spill med ulike digitale verktøy. Noe nytt vil skje … Det sitrer i kropper fylt av forventning. Vi er spente og lengter etter at noe vidunderlig skal skje … (empirisk utsnitt produsert kollektivt av forfatterne).

Bilde 2. (tv). Rommet arrangert som en invitasjon til eksperimentelle utforskinger. Bilde 3. (th). Nærstudie av værskalle.

1. akt

Den første dagen får studentene ingen oppgave, men en oppfordring om å bruke tiden til undersøkelser og eksperimentering med ulike materialer og verktøy. I begynnelsen går det sakte. Det kan virke som om flere synes at det er vanskelig å komme i gang. Rammene for prosjektet er åpne, og vi har lagt få føringer for hvor det skal ende. Den første dagen er satt av til å undersøke, eksperimentere og oppdage uten å tenke på hvor de skal. Vi lar dem gå inn i dette ukjente landskapet, men følger etter på avstand. Etter hvert danner det seg større og mindre grupper som begynner å undersøke materialer i små kollektiver. Vi lar dem holde på en stund, men så blir vi trukket inn av egen nysgjerrighet og utforskertrang. Vi går rundt, og inn og ut av samtaler om ting, teksturer, farger, applikasjoner, motiver, animasjoner, komposisjoner og arrangementer av materialer i rommet. Noen grupper løses opp og studentene arbeider videre på egen hånd. I dag er vi lærere i en lærende, forskende og skapende modus.

Torskeskjelett og macrolinsemagi

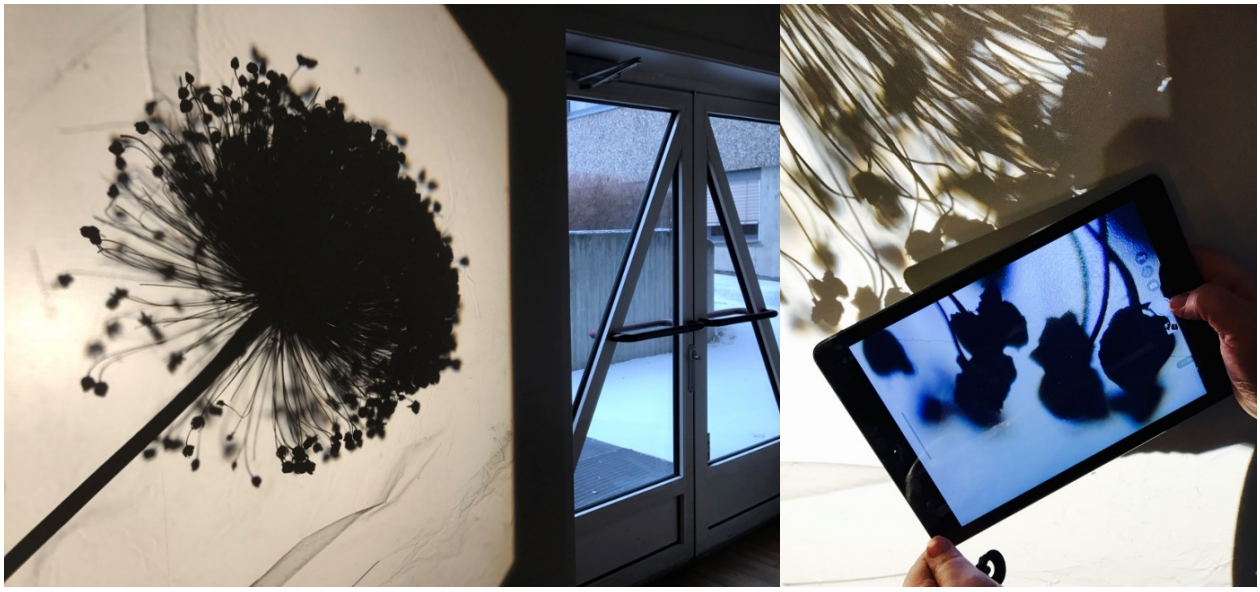
Siri har funnet en del av et torskeskjelett. (se bilde 4). Dette er en av Karis mange skatter. Torskebeinet er en del av et kranium og fargen er gulhvit. Beinstrukturen har ulike tykkelser og

> teksturer. De innerste delene er kompakte, mens de ytterste delene av beinstrukturen er tynne og gjennomskinnelige, nesten som papir. Siri legger kraniet på en hylle av glass inne i et glasskap, og lyser på det med en lommelykt fra undersiden samtidig som hun tar bilder med telefonen sin. Hun tar bilder fra ulike vinkler. Hun holder på en lang stund. Vi tenker at hun har funnet noe interessant. Etter en stund går vi bort og ser på mens hun tar flere bilder. Vi begynner å snakke sammen om torskekraniets ulike materielle kvaliteter. Det som har fanget Siris interesse er form og gjennomskinnelighet, men hun sier at det er irriterende at dette ikke kommer så godt frem på bildene hun tar. Vi henter en makrolinse. Siri setter linsa på telefonen, og vi holder lommelykta. Vi lyser på kraniet fra ulike vinkler, og Siri tar bilder, mange bilder. Hun kommer tett på og er friere siden vi holder lyskilden. Linsa kan ikke zoome, så Siri går tett på torskebeinet med telefon og kropp. Tempoet øker etter hvert som Siri ser hva som åpenbarer seg på skjermen. Vi vet ikke om hun er klar over det, men hun smiler og vi kan fornemme at energien bygger seg opp i takt med de oppdagelsene hun gjør når torskekraniet transformeres til digital materialitet på skjermen. Senere blir bildene til nye transmaterielle landskaper projisert på vegg og lydlagt. (empirisk utsnitt produsert kollektivt av forfatterne).

Bilde 4. Torskeskjelelett sett gjennom makrolinse. Studentfoto. (Gjengitt med tillatelse fra studenten).

I dette empiriske utsnittet får vi innblikk i hvordan undersøkende og eksperimentell tilnærming til materialer kan føre til nye oppdagelser ved bruk av enkel og lett tilgjengelig teknologi. Makrolinsa gjør at motivet forstørres, og du kommer tettere på enn med det blotte øye. Linsa stiller skarpt på deler av motivet, mens andre deler blir uklare og diffuse. Det skapes en dynamikk mellom det skarpe og det uskarpe som bidrar til stor dybdekontrast. Det mest slående er detaljene som forstørres og nærmest står ut av bildeflaten. Blikket endres gjennom kamera. Å forme i fiskebein har lange tradisjoner, men her transformeres ikke materialet fysisk, men digitalt. Torskebeinet transporteres fra fysisk materie til digital materialitet som brukes videre inn i arbeid med video og romlig eksperimentell skapning i det vi har definert som transmaterielle landskaper. I prosjektrommet gjøres det mange slike oppdagelser med makrolinsemagi i undersøkelser av materialer i flyt og skift, fra fysisk uttrykk til digitale uttrykk som smelter sammen i det transmaterielle.

Annes undersøkelse av purreløkblomst og lysbrytninger



Bilde 5 og 6. Foto fra en students utforsking. Bilde 5: En purreløkblomst projisert på vegg. Bilde 6: Detalj fra studentens utforsking av en tørket purreløk-blomst.

> En tørket purreløkblomst og transparent plast projiseres over på en vegg i prosjektrommet. Det er fascinerende at proporsjoner kan transformeres på denne måten – at blomsten transporteres fra hånda og over på hele den hvite veggen ved hjelp av lys og speil (se bilde 5 og 6). Noen deler er skarpe, mens andre er mer diffuse. Dette skaper dybde og variasjon i lys og skygger som utspiller seg på veggen. Farger fra den tørkede blomsten skaper nyanser i brunt. Når Anne fotograferer med nettbrettet blir lys og skygger til digital materialitet på skjermen. Fra tørket purreløkblomst transformert til digital materialitet og transportert ut i rommet, på vegg, på materialer, på mennesker i bevegelse ..., transmaterialitet …(empirisk utsnitt produsert kollektivt av forfatterne).
>
> Anne beskriver møte med prosjektrommet som overveldende, og hun kjenner på følelsen av mangel på kontroll. Hun gir uttrykk for at hun litt tilfeldig går fra materiale til materiale før det er noe som vekker hennes oppmerksomhet. Purreløkblomsten, tørket. Tiden står plutselig stille. Lyset fra lommelykten møtes med dette organiske materialet, noe nytt og annerledes oppstår, hun er i prosessen, beveger seg i ulike vinkler, tar bilde på bilde, fortsetter, fortsetter. Hun setter makrolinsen på nettbrettet og uventede detaljer kommer til syne, hun utforsker, strekker hånden fram for å kjenne på teksturen i den tørre purreløkblomsten. Hun går tettere på, enda nærmere. Magi. Hun er i gang ... Nå fanges oppmerksomheten av skygger i vann i bevegelse. En glassbolle projiseres på en hvit vegg i rommet (se bilde18). Nye oppdagelser. Timene går og hun fortsetter, bruker ord som forelskelse om makrolinsa i møte med de fysiske materialene, hun er på oppdagelsesferd, oppslukt i prosessen. (empirisk utsnitt produsert kollektivt av forfatterne).

I sine materialer og digitale utforskinger i prosjektrommet tar Anne over 300 bilder den første dagen og gjør korte videoopptak av ulike oppdagelser. Hva er det som oppstår i Annes utforsking og videre prosess med materialer og digitale verktøy i prosjektrommet? I notatene fra prosessen beskriver hun at hun starter med å kjenne på frykten for ikke å vite hva hun skal gjøre. Denne deler hun med flere medstudenter. Hun opplever at hun beveger seg i ukjent terreng. Men så blir hun

oppmerksom på hvordan hun kan utforske materialverden i prosjektrommet ved å fokusere på brytning av lys i ulike materialer og hvordan disse filtreres gjennom makrolinsen. Anne oppdager ulike handlingsmuligheter i materialer, verktøy og uttrykk og blir oppmerksom på sin egen sansepersepsjon i prosessen. Vi tror hun beveger seg fra en visuell orientering i rommet til en mer haptisk søken etter nye uttrykk.

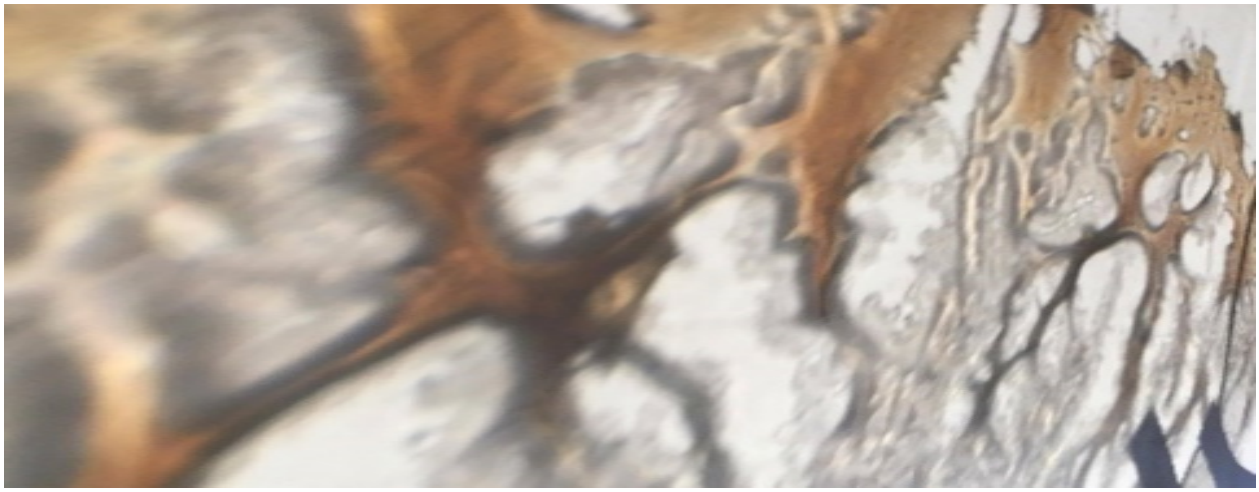
2. akt

Studentene blir introdusert for prosjektperiodens oppgave som er å lage en video med utgangspunkt i de digitale uttrykkene som produseres i eksperimentering og undersøkelser av materialer og fenomener i prosjektrommet. Videoen skal projiseres ut i rommet på nye assemblager av materialer og ting (se bilde 8–14).

Ulike reaksjoner oppstår i studentgruppa og vi kan ane en frustrasjon hos enkelte. I samtaler og veiledning kommer det frem at de gjerne skulle hatt oppgaven først slik at de kunne styre den første dagen med utforsking og eksperimentering mot det endelige målet som er å skape en video. Det er lett å forstå denne frustrasjonen. Svært mange læringsprosesser i utdanningsløpet er målstyrte og lineære. Å arbeide eksplorerende, rhizomatisk og undersøkende er uvant for mange og kan føre til usikkerhet. Hva vil lærerne ha? Hvilke forventninger har vi til det studentene skal levere? Hvordan vil vi som lærere vurdere deres arbeider opp mot hverandre? Hvilke kriterier legges til grunn? Hvilke komponenter skal videoen bestå av? Mange spørsmål svirrer og preger energien i gruppa. Mens noen iler nysgjerrig av gårde inn i ukjent terreng står andre tilbake ved dørterskelen og savner kanskje både kart og kompass?

Det uforutsette

> Det lukter varm brent plast i prosjektrommet. En gruppe studenter er hektiske og litt stresset fordi de nettopp har lagt farget cellofan over en varm arbeidslampe for å undersøke hvordan den fargede plasten påvirker lyset. De oppdager for sent at glasset i lampa er så varmt at plasten smelter i møte med glasset. Den krymper, krakelerer og brenner seg fast i glassplata. De blir oppmerksomme på varmen og den skarpe lukta. Dette er et uhell noe som ikke bør skje på grunn av brannfaren det medfører, men det går bra. Når situasjonen roer seg oppdager studentene at uhellet også fører med seg potensialer for noe nytt. Den smeltede plasten skaper nye mønstre, teksturer og skygger på den hvite veggen (se bilde 7). (empirisk utsnitt produsert kollektivt av forfatterne).



Bilde 7. Smeltet plast på glass – nye digitale landskaper på vegg.

Å arbeide med eksperimentell utforsking handler om å være åpen for det uforutsette. Noen store oppdagelser i laboratorier har vist seg å være uforutsette hendelser, uhell og tilfeldigheter slik som penicillin, bakelitt (plast), cola og rustfritt stål. De handler om å være åpen og søkende i det som oppstår også i det u-planlagte. I denne hendelsen er det uhellet som er starten på noe nytt.

Bilde 8–9. Visuelle utsnitt fra prosessen

Bilde 10–14. Visuelle utsnitt fra prosessen

Etter å ha fått oppgaven går Anne i gang med å planlegge sin videre prosess. Hvordan gjøre et utvalg fra et bildemateriale på 300 bilder? Hvordan velge noe fremfor noe annet? Hvilke grep skal hun ta? Anne har tidligere arbeidet med planlegging, gjennomføring og etterproduksjon i arbeide med video og går i gang. Hun finner en linje å forfølge. Noe har oppstått, det er noen kvaliteter som hun bare må arbeide videre med. Noe har fanget hennes interesse og trigger henne. Det er noe med de monokrome svart-hvitt bildene. Det monokrome uttrykket og de organiske formene har et slektskap med hverandre som forsterkes når bildene settes sammen. De formene hun fester seg ved i

bildematerialet er organiske. Kvaliteter det er vanskelig å beskrive med ord. Hun har gått tett på med makrolinsa slik at den opprinnelige purreløkblomsten dekonstrueres og fremstår som nye linjer, skygger og valører. I detaljene skapes det nye former, nye landskaper (se bilder 15–17). (empirisk utsnitt produsert kollektivt av forfatterne).

Bilde 15–17. Monokrome utsnitt. Nærstudier av skyggespill. Studentfoto. (Gjengitt med tillatelse fra studenten).

3. akt

Det er den siste dagen i prosjektrommet. Noen studenter sier de er stresset fordi de ennå ikke vet hvilke ideer de skal forfølge. Andre er nesten ferdig. Dette øker usikkerheten hos dem som ennå ikke har valgt. Vi lærere går tett på i veiledningen og ber studenter om å vise oss det de har av bilder og dele tanker og ideer, slik at vi sammen kan finne noe som er interessant å forfølge. Ingen skal dra fra samlingen uten å vite hvor de vil.

Kunsten å velge og forfølge oppdagelser

Tiril har arbeidet med vann og farge i en glassbolle. Hun er tydelig fascinert av bevegelser som videoen transporterer og transformerer når hun slipper dråper av tekstilfarge ned i vannet. Dråpen treffer vannoverflata og skaper små krusninger før den beveger seg nedover i vannet i en spiralbevegelse for så å løse seg opp. Vannet blir svakt farget. Det er lett å bli fasinert av disse bevegelsene, men motivutsnittet og kameravinkelen kunne vært bedre for å få frem dette fenomenet. Tiril har undersøkt med flere farger i vannet samtidig. De blander seg og skaper til slutt et grumsete uttrykk. Vi råder henne til å gjøre dette på nytt og arbeide med komposisjon, inn-zooming, gå tettere på og kanskje prøve med bare en farge. Vi merker at hun har motstand mot å gjøre dette om igjen. Det er dette det handler om, sier vi, kjenne på motstand, lokke fram det du opplever er kvaliteter og finslipe uttrykket. Det tar tid å skape gode uttrykk, og det handler om teknikk og håndverk, om komposisjon og presisjon. Etter noen timer viser Tiril frem nye videosekvenser. Hun er i gang med å bearbeide dem ved å redigere filmsekvenser i forhold til klipp, hastighet og lyd. Hun har også funnet en funksjon i applikasjonen som spiller filmen i revers. Hun sa hun trodde det skulle bli kjedelig med bare en farge i vannet, men nå, når hun kan endre på hastighet, klippe og sette sammen sekvenser på nytt og modulere uttrykket med lyd så blir det mange variasjoner, lag og uttrykk i det som skal bli hennes video. (empirisk utsnitt produsert kollektivt av forfatterne).

Igjen blir våre posisjoner som lærere tydelige, og vi opplever også at vi er lærere i kraft av å undersøke, skape og forsterke sammen med studentene. Vi har mange års erfaring med undersøkende praksiser, vi har dybdekunnskap og innsikt i materialer, teknikker, teknologi og de prosessene som studentene går gjennom. Og vi har kunnskaper og innsikter til å se potensialer, muliggjøre og materialisere ideer. Vi har også kraft, iver og mot til bevegelse og nyskaping i våre

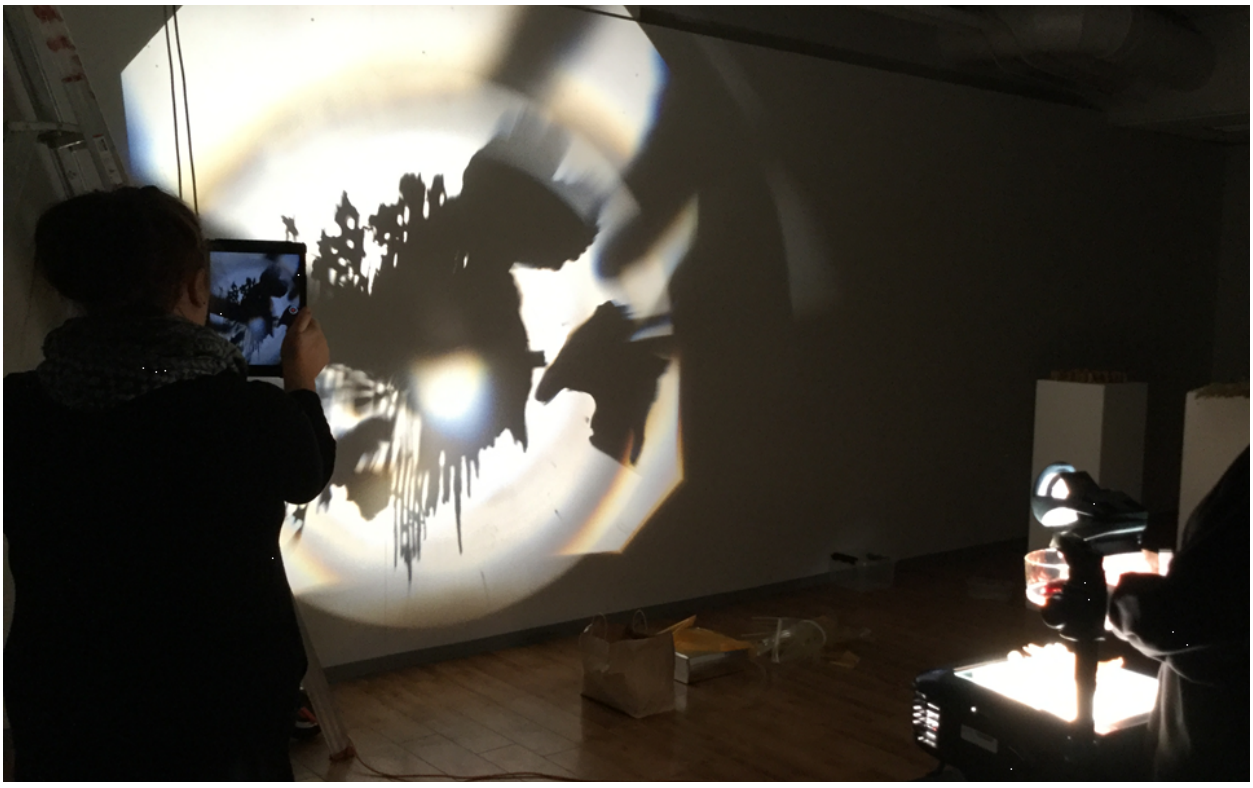
handlinger som forhåpentligvis smitter over på studentene. Vi leter ikke etter studentenes svar, men arbeider for å åpne deres tenkning gjennom handling. Og med tenkning kommer nye spørsmål som kan drive prosesser videre. Tenkning i undersøkelser som gir kraft til rhizomatiske bevegelser. Som a/r/tografer er vi dynamisk og plastisk mellom våre sammenfiltrede perspektiver, som kunstnere, forskere og lærere.

4.akt

Studentene drar hjem med hundrevis av bilder, videosekvenser, tanker og ideer for det videre arbeidet. For å gå tettere på siste fase av undersøkelser og prosesser i de materielle og digitale landskapene i prosjektrommet og sluttarbeidet med video følger vi videre Annes bevegelser og forflytninger i landskapet.

Oppdagelser og uttrykk bearbeidet og transformert til video

> Anne arbeider videre med monokrome uttrykk i stillbildene og de organiske formene som oppstod i møtet mellom lys og purreløkblomst. Hun arbeider med rytme, gjentagelse og tempo i sin video. Hun velger også å bruke en videosnutt med skygger og vann i bevegelse. Denne sekvensen gjentas flere ganger i videoen. Anne kobler sammen lyd og tingenes visuelle form, og viser i sitt refleksjonsnotat en forståelse for dette gjennom henvisning til Köhler (1929). Hun utforsker hvilke lyder som kan samvirke med det visuelle materialet. Hvordan fungerer lyden av rennende vann sammen med stillbildene av organiske uttrykk med utflytende konturer? Lyden av rennende vann forsterker dette flytende oppløste uttrykket. Hun søker og finner lyder som beriker det visuelle uttrykket. (empirisk utsnitt produsert kollektivt av forfatterne).



Bilde 18. Undersøkelser av vann, lys, skygge og bevegelse projisert på vegg og transformert til digitale uttrykk gjennom nettbrettet.

Anne følger sin fluktlinje (Deleuze & Guattari, 1987), og en åpen, eksperimentell og rhizomatisk utforskingen avløses av en formblivelse, en prosess mot et transmaterielt uttrykk. En prosess som skyter fart i en ny retning, som et nytt rotskudd i den rhizomatiske prosessen. En prosess drevet av relasjoner, koblinger og intensiteter som oppstår i samvirke mellom det menneskelige og det ikke-menneskelige i det eksperimentelle.

Retrospektive refleksjoner

I løpet av de prosessene som er utforsket og utviklet gjennom dagene i prosjektrommet har vi opplevd at de kommende barnehagelærerne har reist flere spørsmål som utdyper og differensierer det sentrale forskningsspørsmålet vi har stilt oss: *Hva skjer når vi åpner for eksperimentelle og uforutsette prosesser som transformerer fysiske og digitale fenomener i skapende handlinger?* Erfaringer fra undersøkelsen kan ikke overføres direkte fra prosesser med studenter i en undervisningskontekst til arbeid med skapende prosesser i barnehagen. De kan imidlertid bidra til å oppdage perspektiver som er aktuelle å undersøke sammen med barn i skapende digitale prosesser. Videre i teksten diskuterer vi problemstillinger som kom fram under prosessen, og drøfter dem i lys av de teoretiske inngangene.

Det eksperimentelle og det uforutsette i kollektivt skapende rhizomatiske prosesser

I undervisningsprosjektet har vi lagt som grunnlag at studentene går inn i utforskinger med en åpen og eksperimentell tilnærming ut fra en forståelse av at det er måter å lære på som kan gi andre oppdagelser og muligheter enn lineære og målstyrte prosesser. Det kreves mot (May, 1975) for å slippe taket i trygge vaner og gå inn i ukjente prosesser og landskaper. Å ikke vite hvor eller hva målet er, men være oppmerksom på det som kan oppstå og å forfølge det ukjente. Mange studenter har uttrykt at de har følt motstand når vi forventet at de skulle være i det eksperimentelle og la prosesser få lov til å oppstå og utvikles. Det var utfordrende for dem å skape estetiske uttrykk ved å være i prosessen og ikke forsere den for å skynde seg i mål.

Videre har vi betonet effekten av slike prosesser i et kollektivt læringsmiljø som utspiller seg i prosjektrommet hvor oppdagelser deles og læring kan betraktes som estetiske forfleringer som skyter i ulike retninger som et rhizomatisk rotsystem. Dette er kollektive estetiske læringsprosesser, og delt kunnskap genererer mer kunnskap. I diskusjoner oppstår nye fluktlinjer, «lines of flight» (Deleuze & Guattari, 1987) som potensialer og utvidelser av de landskaper vi sammen skaper. Å utforske sammen åpner for flere veier å gå. Dette ser vi tydelig i det empiriske utsnittet hvor lærere går inn i Siris utforsking av torskeskjelettet og blir medvirkende kraft i form av nye innspill og samhandlinger.

Prosjektrommet som et laboratorium for uforutsette oppdagelser viser seg f. eks. i uhellet med cellofan som smelter fast i glasset på arbeidslampa, krymper og krakelerer. Et uhell som resulterer i nye teksturer og mønstre projisert på veggen. Å utnytte dette uhellet til å se noe nytt handler om å se kunstneriske handlingsmuligheter (affordances) i det uforutsette. Selv om glassplata på arbeidslampa er ødelagt i sin opprinnelige funksjon har den også fått en ny funksjon gjennom en endret materialitet som studentene fanger inn som nye formasjoner i skyggespillet på den hvite veggen som igjen fanges inn av kameralinsa og inngår som transmaterielle uttrykk i nye kunstneriske produksjoner. Et uhell preget av lukten fra smeltet plast som sammenkoblet med videomediets dimensjon *tid* og rommets muligheter fremstår som transmaterielle kvaliteter.

I slike prosesser er det viktig å stoppe opp og reflektere sammen omkring det som har oppstått, det som er oppdaget og det som kan bli noe i en skapende prosess. Som kollektivt skapende gjør vi dette i fellesskap. Det blir synlig for oss lærere hvor ulikt studentene arbeider og hvor ulikt de også

vurderer det de har gjort. Hvor vanskelig det kan være å gi slipp på ideer tidlig i prosessen for å utforske mer og i andre retninger, eller finne gode kvaliteter i et utforskingsmateriale. Å diskutere dette i fellesskap oppleves fruktbart for å åpne opp for å tenke og handle nytt. Vi må være tydelige som lærere og veiledere. Vi må avvente og holde tilbake for å slippe til studentenes initiativer, men også fabulere og brette ut ideer og muligheter for videre skapende prosesser sammen med studentene, med deres oppdagelser og ideer som kunstneriske veiledere.

Teknologier og verktøy

Erfaringer fra undervisningsprosjektet viser tydelig at taktile, visuelle og transmaterielle kvaliteter er avhengige av hvilke redskaper som tas i bruk, men like mye på hvilke måter disse faktisk brukes. Det kreves mye av studenter for å samhandle med ulike typer verktøy og dermed kunne skape nytt handlingsrom for barnehagens materiale og digitale praksis. Mulighetene ligger der, men å gripe dem krever en kvalifisert veileder, og i neste rekke en kvalifisert barnehagelærer, for å skape digitale praksiser som ivaretar det utforskende perspektivet som rammeplanen for barnehagen forutsetter. Teknologien blir virksom som verktøy gjennom handling (Ingold, 2011). Kvaliteter oppstår i måten digitale teknologier tas i bruk på, hvordan handlingsmuligheter materialiseres (Waterhouse, 2013; Carlsen, 2015). Studentene anvender teknologiene innenfor rammen av en skapende prosess og jakter på andre uttrykk enn de ville gjort i en annen undersøkelseskontekst. Når Anne fotograferer utsnitt av skyggespillet til en tørket purreløkblomst, er det i denne sammenhengen ikke en representasjon av purreløkblomsten hun søker, men en utforsking med kamera og muligheter for å oppdage noe nytt, noe hun ikke har sett før. Noe som nettopp makrolinsen, lyssettingen og dynamikken i situasjonen sammen med purreløkblomsten gir mulighet til. En slik bruk av kameraet påvirker vår oppmerksomhet. Verktøyet er i en tett intim relasjon med blikket og kroppen i en åpen, skapende undersøkelse. Når verden filtreres gjennom kameralinsa skjer det en skjerping av oppmerksomheten, gjennom en søker som fokuserer noe inn og utelater noe annet. Det handler om å gjøre valg og bli oppmerksom på det lille i det store, på enheter i assemblager og deres gjensidige virkninger. I dette tilfellet fra det helt konkrete og over i det abstrakte. Når Anne «forelsker» seg i makrolinsa er det teknologiens handlingsmuligheter gjennom hennes blikk som får noe vibrerende til å skje med materialer og fenomener hun fotograferer.

Materialer i flyt, fra materie til transmaterialitet.

Materien blir virksom som materialer i formingsprosesser og i arbeid med digital teknologi transformeres materie og materialer til digital materialitet gjennom kameralinsa. Når digitale uttrykk transporteres ut i rommet gjennom projektoren og smelter sammen med materialer, gjenstander og veggens fysiske materialitet oppstår det vi i denne sammenhengen har definert som transmaterielle (Munster, 2014; Leonardi, 2010) landskaper. Utforskende rhizomatiske praksiser gir åpning for improvisasjoner, oppdagelser, undring og fabulering. Å arbeide med sammenfiltringer av fysisk og digital materialitet åpner for transformasjoner og nye blivelser (Deleuze & Guattari, 1987). Det kan oppstå transformasjoner i det todimensjonale og tredimensjonale, i bevegelse, tempo, overlappinger og gjennom projisering på objekter. Gjennom dette skjer en pågående skapelsesprosess der bilder fra utforskingen gir digitale uttrykk som kan projiseres på nytt og danne grunnlag for nye bilder, tegninger, collager, som lydlegges og blir til film og animasjon.

I vårt undervisningsprosjekt opplever vi at rommet skaper rammer, muligheter, brytninger og intra-agerer med materialer, fenomener og digitale uttrykk, og settes i spill. Rommets ulike teksturer blir virksomme når projektoren projiserer bilder og video på vegg. Rommets plan og linjer brytes når bilder og film projiseres i et hjørne eller i overgangen mellom vegg og tak. På denne måten artikuleres ulike kvaliteter i rommet som glir inn og blir aktive komponenter i utforsking og

eksperimentering av det transmaterielle. Rommet som lerret (Hansson, 2016) og rommet som språk (Rinaldi, 2009) blir virksomt som komponenter i kunstneriske prosesser.

Mot en ny skapende digital praksis i barnehagen

Å arbeide utforskende og eksperimenterende i skapende virksomhet kan åpne for nye formingsfaglige praksiser i barnehagen hvor digital teknologi integreres som verktøy og medium slik at barn får muligheter til å produsere og utveksle kunnskap gjennom digital praksis. På denne måten forskyves barns posisjon fra konsumenter til produsenter av digitale uttrykk. Å være skapende i møter med digital teknologi er et mål i rammeplanen og formingsfaget kan sees som et nav i barnehagens digitale praksis.

I prosjektet *Materiale og digitale landskaper* utvikler studentene kunnskaper i å bruke digitale muligheter for skapende arbeid med digital teknologi blant annet ved bruk av nettbrett. Nettbrettets brukergrensesnitt er intuitivt og i stor grad selv-instruerende. I barnehagen kan det derfor være en fare for at personalet overlater utforskingen til barna alene. I rammeplanen står det at personalet skal; «utforske kreativ og skapende bruk av digitale verktøy sammen med barna» (KD, 2017, s. 45). En kompetent barnehagelærer er reflektert i forhold til å skape rom for reell utforsking og samhandling framfor å la barn sitte alene med applikasjoner der forhåndsdefinerte mål styrer hvilke veier som er mulige å følge. Formuleringer i rammeplanen (KD, 2017) viser til et læringssyn der barn forstås som sansende, utforskende og reflekterende i relasjoner med materialer og omgivelser. Å ta i bruk digitale verktøy og medier i arbeid med romlige uttrykk er en måte å utvide og forflere rommets og verktøyenes muligheter på i pedagogiske og skapende kontekster. Ved å vektlegge kroppslige og sanselige innganger i arbeid med digital teknologi åpnes det for en mer helhetlig og rikere forståelse for det som erfares og læres. Å utforske materialer og materialiteter i transmaterielle landskaper åpner opp for kroppslige og sanselige opplevelser og erfaringer med ulike materialer og uttrykk, både fysiske og digitale. Slik kan utforskende digitale praksiser gi bidrag til fornying og forflering av muligheter i skapende fellesskap for barn og for voksne i barnehagens digitale landskap.

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Publication I (Translated Version)

Experimental explorations of materials and materiality in transmaterial landscapes

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Experimental explorations of materials and materiality in transmaterial landscapes

Summary
This article is based on an arts and crafts educational project in Norwegian early childhood teacher education. Through an a/r/tographic approach, we examine what happens when we open up to experimental, rhizomatic and unforeseen processes that transform physical and digital materials and phenomena into creative processes. The 2017 Norwegian Framework Plan for Kindergartens requires a renewed digital practice in early childhood education and early childhood teacher education. Through combinations of material and digital transformations, new material expressions and possibilities for action in creative processes arise. This article also demonstrates how shared knowledge can accumulate through creative processes in a collective learning environment, based on a rhizomatic understanding of such processes.

Keywords: a/r/tography, experimental processes**,** embodied, rhizomatic, transmateriality, digital practice

Introduction

The empirical study in this article invites you into an arts and crafts educational project with authors and students of early childhood teacher education (ECTE) at the University of South-Eastern Norway (USN). Like the rest of society, early childhood education (ECE) is characterized by rapid technological development. The Norwegian Framework Plan for Kindergartens (Ministry of Education and Research [MER], 2017, pp. 16-17) lays out clear guidelines for digital practice in ECE and gives teachers room for interpretation and action to shape this practice. It requires ECE teachers to acquire new knowledge and understanding of digital potential.

This article focuses on the experience of establishing connections between material-based experimental and creative processes and digital practice in ECE. We focus on explorative processes through various empirical excerpts and theoretical and methodological approaches. We highlight the educational tradition in ECE and strengthen the students' explorative and creative processes in order to increase their digital practice. ECE in Norway is for preschool-age children. Most children in Norway attend ECE from one to six years of age, though this is not mandatory. The tradition of arts and crafts education in Norwegian ECE and ECTE is based on an understanding that acknowledges children's direct experiences with materials and tools as fundamental to their learning (Dewey, 1934/2005). Children explore materials with their whole bodies and relate to the world through their senses (Carlsen, 2015; Eisner, 2002; Fredriksen, 2011, 2013; Waterhouse, 2013). Thelen (2000) underscores that children's physical actions in their environment contribute to shaping their minds. All learning is embodied, grounded in bodily interactions with the environment (Bengtsson, 2013; Gulliksen, 2017; Moser, 2014). Given the emphasis of the tradition of arts and crafts education on children's embodied and affective actions with physical two- and three-dimensional materials, it is worrying that this practice appears to be less firmly rooted in today's ECE than just a few years ago (Carlsen, 2015; Østrem et al., 2009).

We address the challenge implied in the focus of the Norwegian Framework Plan for Kindergartens on digital practice vis-à-vis its emphasis on the importance of embodied learning with physical materials. In the educational project, we challenge ECTE students to explore and create in a material and digital environment. New connections between the physically present and digitally becoming (Deleuze & Guattari, 1987) are incorporated into their knowledge base and are responsible for children's play and learning in ECE. This is what Haraway (2012) defines as "a praxis of care and response – response-ability" (p. 302), an ethical practice that deals with responsibility, action, and response and weaves together materialities and languages in "worldly practices" (Haraway, 1999, p. 109). Barad (2012) follows this thinking around response-ability by adding that it is not about the correct response "but rather a matter of inviting, welcoming, and enabling the response of the Other" (p. 81). Our interwoven educational and research project is about ethical and creative collective practices where the explorative and creative are intertwined into learning processes.

"Becoming" describes something in progress and in movement, a driving force that makes something happen. According to Deleuze and Guattari (1987), becoming cannot be understood as linear, something with a starting and end point; rather, it ought to be understood as something in-between, something that encloses and waves between and through and back and forth. We are entangled in becomings through our explorative creative processes with various materials and materialities. This requires, as we understand it, an openness to what can happen, what can arise in the in-between and in the unforeseen.

Digital technologies are integrated into the educational project as both a tool and a medium. Students and teachers (authors) work experimentally, creatively and exploratively with physical materials, touch devices, light, projectors, smartphones and lenses (macro, wide-angled and fish-eye) that can be used on touch devices and smartphones.

The article answers the following research question: What happens when we open up to experimental and unforeseen processes that transform physical and digital materials and phenomena into creative processes? We illustrate various aspects of this issue through empirical excerpts from the educational project, which can be understood as events, discoveries or small narratives (Waterhouse, 2016). Furthermore, we discuss interactions between students, teachers, materials and tools, arguing for a new, creative, material–digital practice in ECE, where different forms of expression are included in what we describe as "transmaterial" (Munster, 2014) landscapes.

New framework plan, new perspectives

Several studies highlight that the visual and performing arts in ECE are now receiving less attention than before (Bamford, 2012; Carlsen, 2015; Halland & Vist, 2016; Østrem et al., 2009). According to a report from "Følgjegruppa for barnehagelærerutdanninga" (2016) (a study of Norwegian ECTE), this tendency has also been recognized in ECTE. This shifting focus indicates a changed view about what the professional and educational content of ECE should be, with increased pressure on pre-defined learning outcomes (Carlsen, 2015; Otterstad, 2016). Despite the 2017 Framework Plan's emphasis on the exploratory and creative use of digital tools, research shows that there is relatively little exploratory use of digital technology in creative activities in ECE (Bølgan, 2009; Letnes, 2014). This is supported by *Barnehagemonitor 2015 – den digitale tilstanden i barnehagen* (a mapping survey about the digital condition of Norwegian ECE), conducted by the Norwegian Centre for ICT in Education (Jacobsen, Kofoed, & Loi, 2015). According to the survey, there is a general increase in children's use of digital tools, especially as it relates to listening to music, taking pictures and playing games. The study concludes that children appear to be primarily engaged in activities of a consuming nature and less in activities that leave room for creativity. Therefore, there is a need for a renewed digital practice in ECE, with obvious consequences for ECTE. The arts and crafts profession has a particular responsibility for visual competence throughout the educational process, from ECE to higher education. A renewed digital practice must both actively relate to visual expression and include spatial, creative activities that work with digital expressions.

The Framework Plan provides guidelines for digital practice in ECE. The most obvious change from the previous Framework Plan (MER, 2011) is the formulation from *should* to *shall* (MER, 2017) in descriptions of the use of digital tools and forms of expression by children and staff: "The staff must facilitate that children explore, play, learn and create through digital forms of expression", and "the staff shall explore creative use of digital tools together with children" (pp. 16-17). This requires that ECE teachers develop knowledge of digital tools and expressions, both for facilitating creative processes and through explorative and creative processes together with children. The Framework Plan points to the development of a renewed digital practice in collective processes. Under the subject area "Arts, Culture and Creativity", it specifies that ECE shall help children "explore a variety of artistic and cultural expressions" and "use different techniques, materials, tools, and technology to express themselves aesthetically" (p. 51). Finally, ECE "shall help children to have access to things, rooms, and materials that support their playful and aesthetic modes of expression" (p. 19). This underpins the experimental and exploratory aspects found in children's play and aesthetic expression. A change from *should* to *shall* ought to be seen as a consequence of previous discussions about shifting the positioning of children from consumers to producers in digital contexts (Haug & Jamissen, 2015; Letnes, 2014; Waterhouse, 2013).

Early childhood education: new perspectives and new practices

ECE staff shall facilitate children's exploration as well as explore together with children in creative ways. The educational project that forms the basis of this article was carried out in the ECTE course "Material og digital utforsking i formingsprosesser" [Material and digital exploration in creative processes], run in the Department of Visual and Performing Arts Education at the University of Southeast Norway (USN). The course provides a specialization in arts and crafts education and creative processes through different materials, techniques, tools and digital technologies. While the research project has not been finalized, it is entering new phases for each student cohort. The aims are to develop research-based teaching and work with teaching-based research in the context of our own practice as teachers in interaction with our students and, in later phases, with children and staff in ECE. The students' pedagogic and didactic knowledge is linked to their physical experiences. The theoretical framework described below supports this view and points to understandings of materialities, technologies, relations, bodies and knowledge and the experimental and unforeseen in creative processes.

Theoretical framework

Anthropologist Tim Ingold (2007) states that "like all other creatures, human beings do not exist on the 'other side' of materiality but swim in an ocean of materials" (p. 7). The world consists of matter. Matter is part of creative processes as a property of materials. There is increasing scientific evidence supporting that cognition in learning processes is grounded in and shaped by the physical body's experience and interaction in an environment (Bengtsson, 2013; Moser, 2014; Thelen, 2000). We assume that learning is embodied, rooted in bodily interaction and that senses, perception and experience are part of our cognition. This view of learning substantiates the need to participate in explorative processes with materials and tools: "In order to understand cognitive processes we must understand them as features of the whole body (including the brain) and its relation with the environment (i.e., the body embedded in a given environment, the body using different tools in a given environment)" (Raja, Biener, & Chemero, 2017, p. 147). The body as an integrated part of a given environment, in close relation to materials and tools, is a prerequisite for learning.

Psychologist James J. Gibson (1979) introduced the concept of affordance to describe living organisms' relation with the environment and what the environment offers. "An organism interacts with its surroundings by linking the perception of the environment's affordances to action, and cognition or learning is directly linked to the affordances that the environment offers" (Carlsen, 2015, p. 132). It is essential for learning related to materials and technology in creative processes to discover what affordances (Waterhouse, 2013, p. 32) and expressions can be produced by materials

and technologies. This process is about meaningful connections that can materialize in artistic expression.

Our knowledge depends on the context in which it is developed: It is situated (Haraway, 1988). Knowledge is developed in a context or situation, in a specific time and place. If the same materials and things appear in a different context, the learning processes will be different (Waterhouse, 2013). The room is part of the context, filled with limitations and possibilities; within Reggio-Emilia's educational philosophy, it is defined as a third educator, a partner in learning processes (Carlsen, 2015): "The language of the room is very strong and a conditioning factor. Although the code is not always explicit and recognizable, we perceive and interpret it from a very young age. Therefore, like all other languages, physical space also influences the formation of thought" (Rinaldi, 2009, p. 91). According to Hansson (2016), "the ECE room is a flexible medium and a three-dimensional canvas, which can be constantly manipulated and changed" (p. 18).

Seeing materials, things and technologies as performative can.make room for curiosity and receptivity of what is happening, what is being discovered and the unforeseen (Häikiö, 2017). Learning in exploratory and experimental creative processes requires a relation between content, drive and interaction.

About rhizomes and intra-actions in experimental and explorative practices

Experimental and explorative methods in creative activities are strategies to make new discoveries. According to Welsch (cited in Blume, 2015), things are explored in new ways, and an experimental practice opens up spaces of infinite potential. Experimental processes require creative wealth, reflection and a driving force, and the process is advanced by a continuous change in and through observation and action. Experimental processes seek something that is not defined in advance, something that results from action. This requires being open to the unforeseen and building on an understanding that intuitive elements occur through explorative processes (Blume, 2015). It is about letting coincidences happen and seeing the value in them. Such processes can be seen as assemblages of things, ideas and structures that move like waves and create new connections and becomings, enabling the development of new knowledge and insights.

Such a rhizomatic process is not linear; it shoots off in different directions. Linking events and phenomena in different ways, it reshapes and transforms. The term "rhizome" is derived from botany. It has since been developed as a philosophical concept by Deleuze and Guattari (1987) and has been used in recent ECE research and pedagogical literature. The term refers to a type of root system in which the plant has no main root, but a network that shoots new roots in different directions. They intersect and often lie close, like a tissue or carpet, under the soil's surface. Examples of Norwegian plants that grow rhizomatically are the nettle root (Figure 1), wood anemone, polypody and ground-elder. In a creative experimental learning process, the rhizomatic can provide many openings and potentials and innumerable opportunities or "lines of flight" (Deleuze & Guattari, 1987) that can be pursued through open and experimental approaches (Olsson, 2014).

Collective aesthetic learning processes can also allow for enhanced learning through aesthetic doubling (Austring & Sørensen, 2006, p. 172). The knowledge produced in the collective is accumulative, which means that the group's overall knowledge grows faster than if the individual had undergone learning processes outside the collective. The doubling lies in the fact that the participants of the collective support and complement each other's explorations. Knowledge and insights are constantly being developed and shared. We choose to see this not just as doubling but as multiplying.

Figure 1. Nettle Root. E. Korsmo's weeds charts. Exhibited in the Botanical Garden, Oslo.

In art and craft processes, it is not solely the individual and others in a learning collective who interact with each other. The physical environment, materials and tools that are part of a situation, which constitute an assemblage (Deleuze & Guattari, 1987), are important to the processes that take place. A lexical definition of assemblage is a "work of art composed of different materials; also the term for a technique, originally a three-dimensional version of collage" (Assemblage: kunst, 2018). Assemblage as a philosophical concept is related to Deleuze and Guattari's (1987) process ontology and comes from the French word *agencement*, "…a term that refers to the action of matching or fitting together a set of components (*agencer*), as well as to the result of such an action: an ensemble of parts that mesh together well" (Delanda, 2016, p. 1).

> Nor are assemblages exactly things. They are also processes of perpetual self-construction. The French *agencement*, translated as 'assemblage', can mean both an arrangement of things and the act of arranging those things. An *agencement* thus is not just an assemblage of things, but also a process of 'agencing', just as a circuit of desiring-machines is a 'machining' of machines, an active bringing-into-existence of its own circuitry. (Bogue, 2007, pp. 145-146)

An assemblage can thus be understood as an arrangement of various units (materials, objects, bodies) and the performative arising from the effects of interconnections between the units in an assembly. The aesthetic learning process can be seen as an intra-active phenomenon that incorporates both people and non-humans into the collective, meaning-making process. The perspective is shifted from inter-active relationships to intra-active phenomena that encompass both living and non-living actors in the environment of a given situation. In intra-active phenomena, different identities operate in a common process whereby both meaning and form are created (Barad, 2008; Carlsen, 2015). With this perspective, power is shifted and distributed from people acting unilaterally in the process to the

vibrating and active spaces between people, things and materials as performative in both the process and assembly. In ECE, this can mean that it is possible to understand the sand in the sandbox, the clay, the building blocks and the dough as actively participating with the children in creative processes. Similarly, the students' exploration of, for example, a dried leek flower (see Figures 5 and 6) and exchange of knowledge are entirely dependent on the interaction with tools such as a touch device, smartphone and projector. Physical materials, along with the digital tools and applications available, provide direction for what is possible to explore in the context. At the same time, the expressions and knowledge produced along the way are left open.

Technologies, tools and embodiment

"No object considered purely in and for itself, in terms of its intrinsic attributes alone can be a tool. To describe a thing as a tool is to place it in relation to other things within a field of activity in which it can exert a certain effect" (Ingold, 2011, p. 56). According to Ingold, tools are things that become tools through performative action and in relation to the material process in which they are used. A saw becomes a tool when someone uses it to cut a piece of wood. To define things as tools is to link them to action.

By using tools, we are acting not only in the world but also in a process of understanding the world (Ingold, 2011). Technology is mainly associated with the human-made world, although some animal species also use tools. However, tool usage relates to the non-human-made world, nature, matter and phenomena. Throughout history, humanity has developed and adopted various technologies, such as tools and machines, into everyday life and creative actions. Technology deals with everything from simple hand tools, such as knives and paintbrushes, to advanced technology, such as robots: "A tool is a sort of extension of the hand, almost an attachment to it or a part of the user's own body" (Gibson, 1986, p. 41). Tools relate to the body in action (Ingold, 2011). Digital technologies, such as touch devices and smartphones, engage in intra-actions with bodies, materials and the environment. The development of digital technologies involves a change in human–machine relations. This is referred to as human–computer interaction (Farr, Price, & Jewitt, 2012). The technology in tangible digital mobile devices with multi-touch features provides opportunities to explore a wide range of perception-based actions (Farr et al., 2012).

Materials, materiality and transmateriality

According to Ingold (2007), materiality is not tangible in the same way as matter and materials. Defining materiality is, therefore, not simple:

> I can touch the rock, whether of a cave wall or of the ground underfoot and can thereby gain a feel for what rock is like as a *material*. But I cannot touch the *materiality* of the rock. The surface of materiality, in short, is an illusion. (p. 7)

Ingold states that materiality is an illusion, but what does this mean? In everyday Norwegian speech, we can say that something is materializing, that it takes shape and becomes visible to us. In her doctoral dissertation, Nordtømme (2016) analysed children's play through space and materiality, writing that she used materiality in her study as a common term for things and materials (p. 1). However, is this what materiality is? Herein, it is concrete and tangible, contrasting Ingold's understanding of materiality as an illusion. Materiality has to do with matter and materials, but it is more than the things and materials that surround us. Materiality can be seen as an intra-active and performative phenomenon (Barad, 2007). It is something that both is and does. It includes the effects of relations, in which sense, it is not tangible and can, therefore, be seen as an illusion – in line with Ingold's definition. Nevertheless, it also relates to something concrete and tangible, the way Nordtømme uses the term. The relations between humans and matter/materials can, as we see it, be termed an intra-active relation with mutual influence between humans and matter/materials. Meaning and form are created in an active space between matter/materials and people in action

(Carlsen, 2015; Lenz Taguchi, 2010), and materiality becomes, as we apply it in this context, the relations between people and materials and the effects that arise from actions in intra-active relations. Materials such as sand, plastic, textiles, paper and water have a substance that can be touched and manually altered. They are materials with physical properties, such as consistency, texture and colour. Some materials are closely related to nature, such as clay, wood and sand, while others are processed or in the process of transformation. Plastic is one such material, which originated in crude oil and, through processing, can end up as cellophane and plastic bags. Knowledge of materials in production processes, in "material flow" (Ingold, 2007), provides insight into the properties of materials, their resistance and opportunities and their affordances (Carlsen, 2015; Fredriksen, 2011; Waterhouse, 2013). Materiality – such as light, shadow, movement, light refraction, and degrees of transparency – experienced, for example, through the camera lens, refers to phenomena that can act as materials. They can be used as elements in creating artistic expressions. These phenomena are volatile and intangible, but it is still possible to process and apply them as material elements in creative processes (Waterhouse, 2013).

Digital materiality (Leonardi, 2010) is made available through technological devices or transformed through printing into two- or three-dimensional expressions or things. The properties of digital materiality differ from those of physical materials and are independent of the conditions of physical materials, such as gravity. The experience of digital materiality is an amalgamation of visual, auditory and physical material, e.g. touching the surface of a touch device. Digital materiality in creative processes can be expressions produced with, for example, video and photos, which are integrated as material components in a room together with other types of phenomena and matter/materials. Physical matter and phenomena are transported through digital tools and transformed in space as a response to various surfaces and textures in the environment. Transmaterial expressions (Munster, 2014) occur when different physical materials and materialities are intertwined with digital materiality (Leonardi, 2010). Transmateriality can be understood as "matter in movement, matter as relations of forces, matter as an energetics" (p. 158). Transmateriality is matter/materials in transformation, not in form but from their physical form to signals and codes processed through digital devices, transported and transformed in time and space.

Ingold (2013) states that "in the art of inquiry, the conduct of thought goes along with, and continually answers to, the flux and flows of the materials which we work with. These materials think in us, as we think through them" (p. 6). Through creative processes, we open up to follow and act with matter and materials in transformations or "material flow" (Ingold, 2013). In such processes, we can exchange knowledge through interactions between people, matter, materials and technology. "To describe the properties of materials is to tell the stories of what happens to them as they flow, mix and mutate" (Ingold, 2007, p. 14).

Methodological entrances

Through participatory observation and collective explorations in the project room, we as teachers, artists and researchers come close to the students' explorations. Through experiments in the project room, insights and relations are developed in relation to materials and phenomena and how they mutually influence each other. Personal experience is an important path through which to access knowledge in qualitative research of an experimental nature (Bresler, 2006; Stake, 2010). In teaching and guidance, we explore together with the students and position ourselves as a/r/tographers (Springgay, Irwin, Leggo, & Gouzouasis, 2008):

> A/r/tography as practice-based research is situated in the in-between, where theory-as-practice-as-process-as-complication intentionally unsettles perception and knowing through living inquiry. (p. xxi)

A/r/tography is a practice-based research methodology within art-based research (Barone & Eisner, 2012; Rolling, 2010). Through this methodology, art, research and teaching (learning) are

interwoven through the researcher, who is an artist, researcher and teacher (A/R/T). Creation and writing complement each other in the study: "it is a process of double imaging that includes the creation of art and words that are not separate or illustrative of each other but instead, are interconnected and woven through each other to create additional meanings" (Springgay, Irwin, & Kind, 2005, p. 899).

A/r/tography is a research methodology that, through a person's actions, performs, curves and twists like a rhizome (Springgay et al., 2008). Methodologically, it is open and unpredictable, driven by creative processes that branch out into becomings: "There are no points or positions in a rhizome, such as those found in a structure, tree, or root. There are only lines" (Deleuze & Guattari, 1987, p. 8), which intersect, diverge, move and curve.

Artistic and creative processes can be understood as ways of exploring the world, or "worldly practices" (Haraway & Goodeve, 1999). Through artistic activity, new knowledge can be produced in exchanges between human and non-human entities in creative intra-active processes (Barad, 2007).

"Learning/creating/inquiring in, from, though, and with situations occurs in the in-between spaces – those spaces that make connections that are often unanticipated" (Irwin et al., 2006, p. 72). Through the three identities of the research position A/R/T (Irwin et al., 2006), which are entangled, different and tangible, we as researchers gain insight into teaching contexts and learning processes through joint exploration, learning and reflecting together with students, i.e. learners who are also creative and explorative. We explore possibilities and potentials in spaces between the human and non-human and the creative, explorative, and learning.

We used excerpts and descriptions of events in the project room as part of the empirical material for this article and our retrospective reflections. The descriptions are a way of recreating some of the experiences from the project room for the reader. The empirical basis of the article as a whole is formed by our preparation for teaching, our own observations, the documentation of the teaching project, collective exploration, students' verbal utterances, processes and expressions, photographs and video.

Scenes from a project room

> We are excited. For many days now, we have been working to prepare ourselves and the large project room for the students' exploration of what we call material and digital landscapes. We are excited because we do not quite know what will happen when the students enter the room. The room is tidy. White podiums have been placed on the floor, creating small plateaus where materials are laid out and arranged in assemblages (see Figures 2 and 3). Kari lends out treasures collected over the years. Here, we find dried red cabbage and slices of dried orange, cones, a dried leek flower, bark, mushrooms, seeds, dried leaves, stones, sand, a reed and pieces of wood – an arrangement of organic things and materials of different qualities and smells … We have also found cardboard, paper, glass, mirrors, cellophane, textiles and mirrors: an arsenal of materials with varying degrees of translucency. There are wooden sticks, plastic tubes, cardboard tubes, plexiglass sticks and much more … We feel our bodies trembling. We want to put our hands in this! Feel, lift, stroke and smell. The fragile qualities of the dried cabbage leaves and congealed seeds fascinate. Light, gauzy, woven textiles join a small nest that has persistently and systematically been woven by a bird. The materials and things invite action in different ways. What happens when the students get into action? Do they want to feel, stroke and explore? Will anyone crush a dried leaf between their fingers and rejoice at the sound being created? Will someone lift a mirror, hold it up against the light, move it back and forth to see how the light is refracted and reflected by the material? Will they feel a desire for the materials? … Students will soon be invited in to explore materials and experience transformations in using different digital tools. Something new is going to happen … Our bodies are trembling, filled with anticipation. We are excited and eager for something wonderful to happen … (Empirical excerpt produced collectively by the authors)

Figure 2. The project room is arranged as an invitation to experimental exploration. Figure 3. Close study of a buck skull.

First act

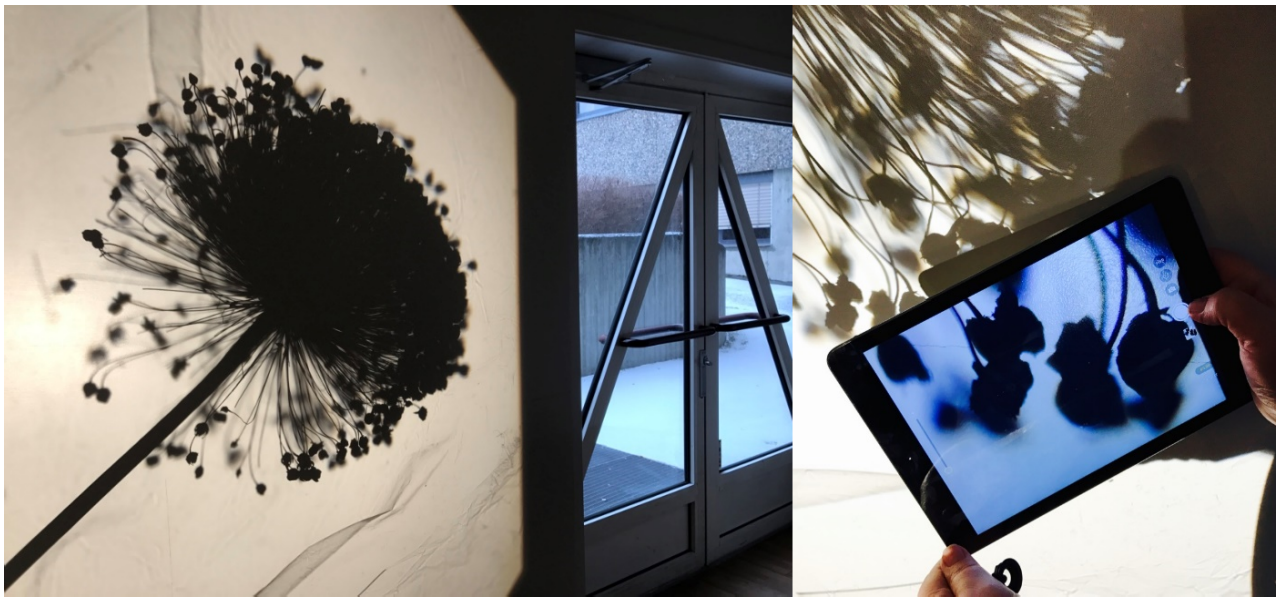
On the first day, students are not given an assignment but, rather, are requested to spend time exploring and experimenting with different materials and tools. At the beginning, things proceed at a slow pace, and several students seem to find it difficult to get started. The framework of the project is open, and we have laid out a few guidelines about where it could end. The first day is set aside to explore, experiment and discover, without thinking about where to go. We let them into this unknown landscape and follow them from a distance. Gradually, larger and smaller groups begin to form, exploring materials in small collectives. We let them be for a while, but then, we are drawn in by our own curiosity and explorative drives. We walk around and discuss things, the textures, colours, applications, motifs, animations, compositions and arrangements of materials in the room. Some groups dissolve, with individual members deciding to work independently. Today, we are teachers in a learning, research and artistic/creative mode.

> *Cod skeleton and macro lens magic*
> Siri has found part of a cod skeleton (see Figure 4). This is one of Kari's many treasures. The bone is part of a skull, and the colour is yellowish white. The bone structure has varying degrees of thickness and different textures. The inner parts of the bone structure are compact, while the outer parts are thin and translucent, almost like paper. Siri places the skull on a shelf of glass inside a glass cabinet and lights it with a flashlight from the underside while taking pictures with her smartphone. She takes pictures from different angles. She continues for a long time. We think that she has found something interesting. After a while, we walk towards her and watch as she takes more pictures. We start discussing the different material qualities of the cod bone. What have captured Siri's interest are form and translucency, but she says that it is annoying that this has not come out so well in the pictures she has taken. We then get a macro lens, which Siri attaches to her smartphone, and we hold the flashlight. We light the skull from different angles, and Siri takes pictures, many pictures. She comes close; she is freer now, since we are holding the light source. The lens does not have the zoom function, so Siri gets close to the cod bone with the phone and her body. The pace increases, as she sees what is revealed on the screen. We do not know if she is aware of this, but she smiles, and we can sense that her energy is building up in line with the discoveries she is making, as the cod skull is transformed into digital materiality on screen. Later, the images of new transmaterial landscapes are projected onto the wall, and sounds are added to the images. (Empirical excerpt produced collectively by the authors)

Figure 4. Cod skeleton seen through a macro lens. Student photo (Reproduced with permission from the student).

In this empirical section, we gain insight into how explorative and experimental approaches to materials can lead to new discoveries through the use of simple and readily available technology. The macro lens magnifies the subject, and the photographer can get closer than with the eye alone. The lens focuss sharply on some parts of the subject, while others become fuzzy and diffuse. A dynamic is created between the sharp and the blurred, which contributes to a great contrast in terms of depth. Most striking are the magnified details that almost stand out from the image's surface. What is perceived is changed through the camera lens. Carving in fishing bones has a long tradition, but here, the material is digitally, not physically, transformed. The cod is transported from physical matter to digital materiality, which is further used in work with video and spatial experimental creations in what we have defined as transmaterial landscapes. In the project room, many such discoveries are made with macro lens magic through studies of materials in flow and shift, moving from physical to digital expressions that fuse together in transmateriality.

Exploration of a dried leek flower and light refraction



Figures 5 and 6. Photo from a student's exploration. Figure 5: A leek flower projected onto the wall. Figure 6: Detail from the student's exploration of a leek flower.

> A dried leek flower and transparent plastic are projected onto a wall in the project room. It is fascinating that proportions can be transformed in this way. The flower is transported from the hand to the entire white wall by light and mirrors (see Figures 5 and 6). Some parts are sharp, while others are more diffuse. This creates depth and variation in the light and shadows that play out on the wall. Colours from the dried flower create shades of brown. As Anne photographs with the touch device, light and shadows turn to digital materiality on the screen. From the dried leek flower transformed to digital materiality and transported out into space, on the wall, on materials, on moving people … transmateriality … (Empirical excerpt produced collectively by the authors)

> Anne describes her experience with the project room as overwhelming, as she senses a lack of control. She expresses that she goes randomly from material to material before something catches her attention. The leek flower has dried up, and time suddenly stands still. The light from the flashlight hits this organic material. Something new and different arises: She is in the process, moving at different angles, taking pictures, continuing, continuing. She puts the macro lens on the touch device, and surprising details appear. She explores, reaching out to feel the texture of the dried leek flower. She gets closer, even closer. Magic! She is in the process … Shadows in moving water have now caught her attention. A glass bowl is projected onto a white wall in the room (see Figure 18). New discoveries. The hours pass by, and she goes on, using phrases such as "being in love with the macro lens" and using them to explore the physical materials. She is on a journey of discovery, engrossed in the process. (Empirical excerpt collectively by the authors)

In her material and digital exploration in the project room, Anne takes over 300 photos on the first day and makes a short video footage of various discoveries. What happens in her exploration and processing of the digital tools and materials in the project room? In the notes from the project, she starts with the experience of the fear of not knowing what to do. She shares this with several fellow students. She feels that she is moving in unfamiliar terrain. Then, she becomes aware of how she can explore the material world in the project room by focusing on the refraction of light in different materials and how they are filtered through the macro lens. Anne discovers various possibilities for action in materials, tools and expressions, and she becomes aware of her own sense perception in the process. We think that she is moving from a visual orientation in the room to a more haptic search for new expressions.

Second act

The students are introduced to the assignment relating to the teaching project, which is to create a video based on the digital expressions produced in the experimentation and exploration of materials and phenomena in the project room. They are encouraged to project their videos onto new assemblages of materials and items (see Figures 8–14).

Different reactions occur in the student group, and we can feel that some of the students are becoming frustrated. Through conversations and guidance, some of them express that they would rather have had the assignment before they started so that they could steer the first day of exploration and experimentation towards the ultimate goal of creating a video. It is easy to understand this frustration. Many learning processes in education are linear, with pre-defined learning outcomes. Exploratory and rhizomatic ways of working are unfamiliar to many and can lead to uncertainty. What do the teachers want? What expectations do we have of the students? How do we as teachers evaluate their work against each other? What criteria are used? What components should the video consist of? Many questions swirl and characterize the energy of the group. While some rush curiously into unfamiliar terrain, others are left at the doorstep and may miss both the map and compass.

The unforeseen

> It smells of hot, burned plastic in the project room. A group of students are frantic and a bit stressed because they have just put coloured cellophane over a warm work lamp to explore how the coloured plastic affects the light. They discover too late that the glass in the lamp is so warm that the plastic melts on contact with it. It shrinks, crackles and burns to the glass plate. They become aware of the heat and the pungent smell. This is an accident which should not have happened because of the fire hazard entailed, but it is going well. When the situation calms down, the students discover that the accident also brings a potential for something new. The melted plastic creates new patterns, textures and shadows on the white wall (see Figure 7). (Empirical excerpt produced collectively by the authors).

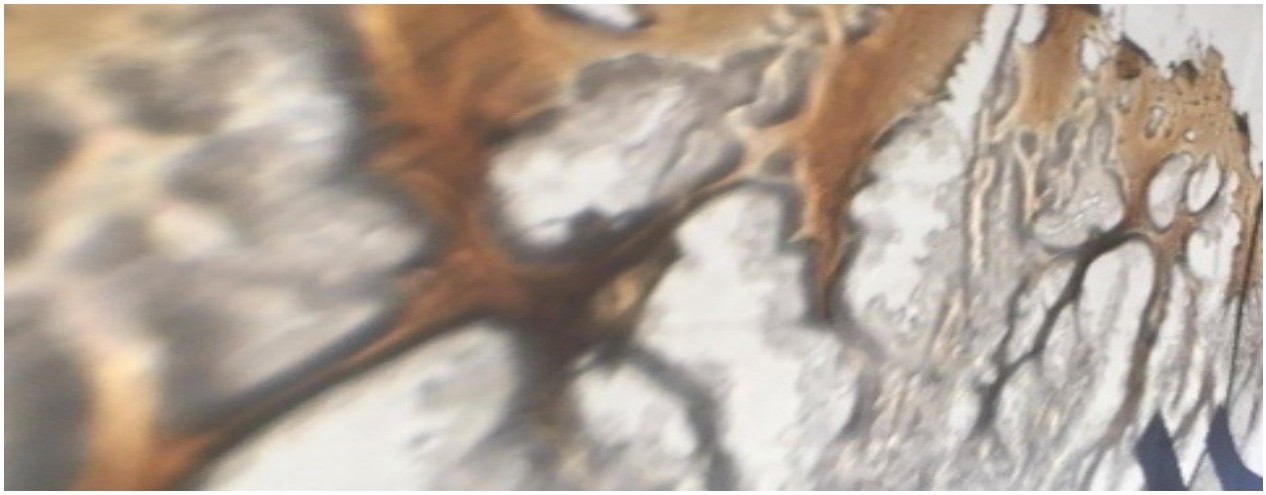


Figure 7. Melted plastic on glass – new digital landscapes on the wall.

Working with explorative and experimental processes necessitates being open to the unforeseen. Some major laboratory discoveries were the result of accidents and incidents, such as penicillin, bakelite (plastic), cola and stainless steel. Discoveries are about being open and searching for what occurs in unplanned occurrences. In this event, the accident is the start of something new.

Figure 8 and 9. Visual excerpts from the processes.

Figure 10–14. Visual excerpts from the processes.

After receiving the assignment, Anne starts planning the next stages of her process. It is difficult to select from the 300 photos she has taken. How does one choose one thing over another? What strategy should she use? Anne has previously worked with planning, implementation and video production, and she is getting started. She finds a line worth pursuing. Something has occurred: There are some qualities that she just has to work on. Something has captured her interest and triggered her. There is something about the monochrome, black and white photos. The monochrome expression and organic forms have a relation, which is enhanced when the photos are put together. She adheres to the organic shapes in the visual material, qualities that are difficult to describe in words. She has worked closely with the macro lens so that the original leek flower is deconstructed, appearing as new lines, shadows and denominations. Through the details, new forms and landscapes are created (see Figures 15–17). (Empirical excerpt produced collectively by the authors)

Figure 15–17. Monochrome excerpts. Close-up studies of shadow in movement. Student Photography (Reproduced with permission from the student).

Third act

It is the last day in the project room. Some students say that they are stressed because they do not yet know what ideas to pursue. Others are nearing the end, which increases the uncertainty of those who are yet to choose an idea. As teachers, we follow closely through guidance and ask students to show us their photos and share their thoughts and ideas so that we can find something of interest to pursue together.

The art of choosing and pursuing discoveries

> Tiril has worked with water and colour in a glass bowl. She is clearly fascinated by the movements that the video transports and transforms when she drips drops of textile colour into the water. Each drop hits the water's surface and creates small ripples before moving down the water in a spiral motion and dissolving. The water becomes slightly discoloured. It is easy to be fascinated by these movements, but the subject excerpt and camera angle could have been better for this phenomenon. Tiril has explored with several colours in the water simultaneously. They blend in and eventually create a murky expression. We guide her to do this again and work on composition, zooming in, going closer and perhaps trying with just one colour. We notice her resistance to repeat the process. This is what it is about, we say: feeling resistance, eliciting what you experience as qualities and fine-tuning the expression. It takes time to create good expressions, and it is about technique and artistry, composition and precision. After a few hours, Tiril shows us new video sequences. She is in the process of editing video sequences in terms of clips, speed and sound. She has also found a feature in the application that plays the movie in reverse. She said that she thought that it would be boring with just one colour in the water, but now that she can change speed, cut and reassemble sequences and modulate the expression with sound, there will be many variations, layers and expressions in what is going to be her video. (Empirical excerpt produced collectively by the authors)

Again, our position as teachers becomes clear, and we experience that we are teachers in processes wherein we explore and create together with students. We have many years of experience in explorative practices; we have in-depth knowledge and insight into the materials, techniques, technology and processes that the students employ. We also have the knowledge and insights to see potential, to enable and materialize ideas. We have the power, zeal and courage to allow movement and innovation in our actions, which will hopefully affect the students. We are not looking for students' answers; rather, we are working to develop their thinking through action, and with thinking comes new questions that can drive processes further, thinking through exploration that gives power to rhizomatic movements. As a/r/tographers, we are dynamic and in movement between our tangled perspectives as artists, researchers and teachers.

Fourth act

Following the teaching project, each student would have collected hundreds of photos, video sequences, thoughts and ideas for further work. In order to get closer to the final phase of exploration and processes in the material and digital landscapes of the project room and the final work on the video, we follow Anne's movements in the landscape.

Discoveries and expressions processed and transformed into video

> Anne continues to work with monochrome expressions in the photos and organic forms, which emerged in the meeting between the light and the leek flower. She works with rhythm, repetition and tempo in her video. She also chooses to use a video clip with shadows and water in movement. This sequence is repeated several times in the video. Anne connects sound with the visual form of things, and in her reflection notes, she shows an understanding of this through her reference to Köhler (1929). She explores the connection of sound and organic form in the visual material. How does the sound of running water work with photos depicting organic expressions with flowing contours? The sound of running water reinforces this fluid, dissolved expression. She seeks and finds sounds that enrich the visual expression. (Empirical excerpt produced collectively by the authors)

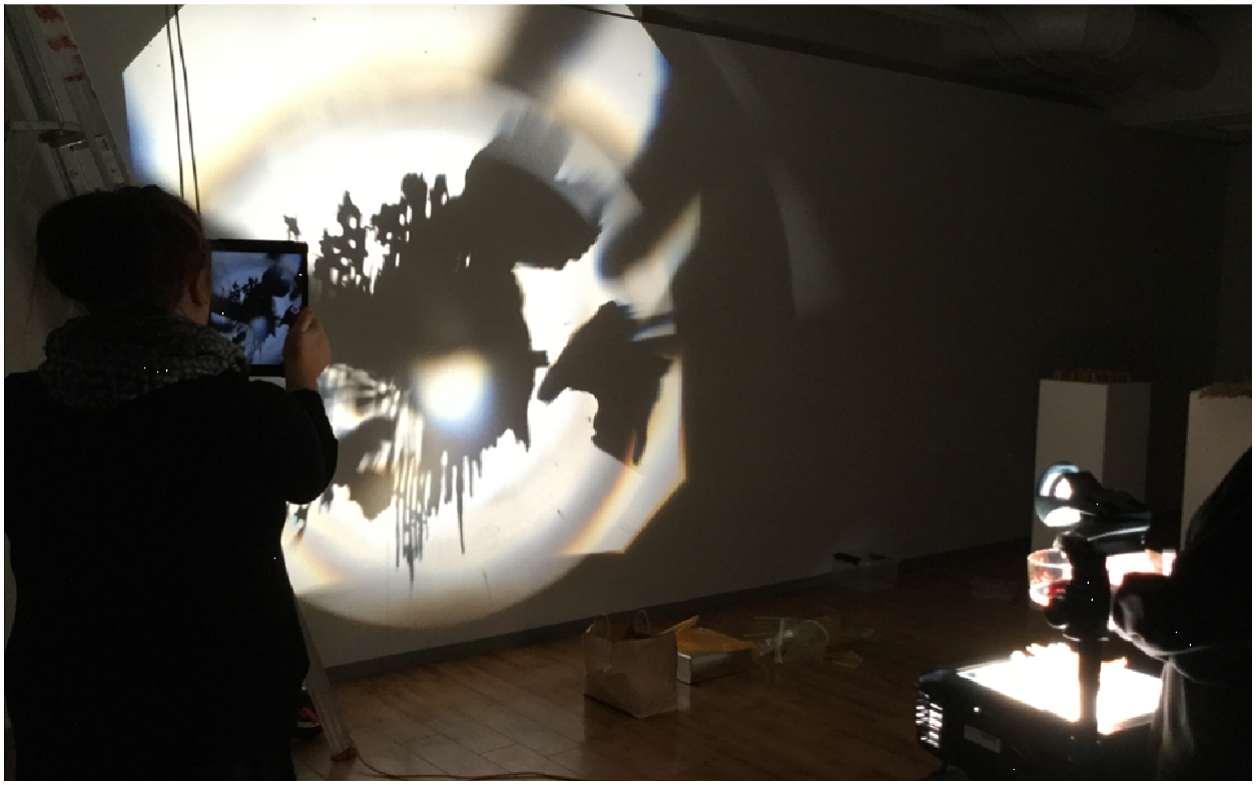


Figure 18. Exploration of water, light, shadow and movement is being projected onto the wall and transformed into digital expressions through the touch device.

Anne follows her lines of flight (Deleuze & Guattari, 1987), and an open, experimental and rhizomatic exploration is replaced by a form of becoming, a process towards a transmaterial expression: a process that accelerates in a new direction, like a new root shot in the rhizomatic process; a process driven by relations, connections and intensities that arise in the interaction between the human and non-human in the experimental.

Retrospective reflections

Through the processes that were explored and developed during the days in the project room, we experienced that these soon-to-be ECE teachers had raised several questions that deepened and differentiated the central research question asked: What happens when we open up to experimental and unforeseen processes that transform physical and digital phenomena into creative processes? Experiences from the study cannot be transferred directly from the students' processes to working with creative processes in ECE. However, these experiences can help them understand what it means to make these discoveries, especially for the first time, and to make discoveries that are relevant to explore in creative digital processes. Further, in this article, we discussed issues emerging during the process in light of the theoretical framework.

The experimental and unforeseen in collectively creative rhizomatic processes

In the teaching project, we have laid the foundation for the students to enter into explorations with an open and experimental approach based on an understanding that there are ways of learning, besides linear and goal-directed processes, that can enable discoveries and opportunities. It takes courage (May, 1975) to let go of safe habits and enter into unknown processes and landscapes, to not know where or what the goal is and to be open to what might occur and pursue the unknown. Many students expressed that they felt resistance when we expected them to be in an experimental process and allow processes to arise and develop. It was challenging for them to create aesthetic expressions by being in the process and not rushing to finish it.

Furthermore, we emphasized the effect of such processes taking place in a collective learning environment, where discoveries are shared, and learning can be regarded as an aesthetic process that bows in different directions, much like a rhizomatic root system. These are collective aesthetic learning processes, and shared knowledge generates more knowledge. In the discussions, new "lines of flight" arose (Deleuze & Guattari, 1987) as potentials and extensions of the landscapes that we created together. Exploring together opened up several avenues. We could see this clearly in the empirical section wherein the teachers entered Siri's exploration of the cod skeleton and became a contributing force in the form of new input and interactions.

The project room turned out to be a laboratory of unforeseen discoveries, which happened accidentally in the case of cellophane, which melted, shrunk and crackled into the glass of the working lamp. This accident resulted in new textures and patterns projected onto the wall. Utilizing this mishap to see something new is about seeing artistic opportunities and affordances in the unforeseen. Although the glass of the work lamp was destroyed with respect to its original function, it acquired a new function through a changed materiality – which the students captured as new formations in the shadow play on the white wall – which was also captured by the camera lens and became a transmaterial expression in new artistic productions. An accident characterized by the smell of melted plastic, coupled with the video media's dimension of time and the possibilities of the room, appeared as transmaterial qualities.

In such processes, it is important to pause and reflect together on what has occurred, what has been discovered and what **else** could be included in the creative process. In a collective learning process, we do this jointly. It became obvious to us teachers how different the students' work was and how differently they evaluated their own processes and products. It was also obvious how difficult it can be to let go of ideas early in the process in order to explore further and in other directions or to find good qualities in the material being explored. Discussing this jointly felt fruitful, opening up thoughts and finding new ways of interacting. We must be clear as teachers and supervisors. We must wait and hold back before revealing or figuring out the students' initiatives, but we must also formulate and expand ideas and opportunities for further creative processes with the students and their discoveries and ideas as artistic guidance.

Technologies and tools

Our experience from the teaching project reveals that tactile, visual and transmaterial qualities

depend on which tools are being used and how. It requires many students to interact with different types of tools and, thus, create new material and digital practices and facilitate a creative process in ECE. The opportunities are present, but seizing them requires a qualified supervisor and, consequently, a qualified ECE teacher to create digital practices that safeguard the exploratory perspective required by the Framework Plan for Kindergartens. Technology becomes performative as a tool through action (Ingold, 2011). Qualities arise in the way that these digital technologies are used and how affordances are materialized (Carlsen, 2015; Waterhouse, 2013). Students use the technologies within the framework of a creative process and search for expressions in a way that differs from what they would have used in a different context. When Anne photographed details of the moving shadows of the dried leek flower, she was not seeking a representation of the leek flower. She was seeking an exploration with the camera and the opportunity to discover something new, something she had not seen before. This is something that the macro lens, the lighting and the dynamics of the situation, together with the leek flower, opened up and allowed. Such use of the camera affected our attention. The tool was in a close, intimate relationship with the gaze and the body in an open, creative process. When the world is experienced through the filter of the camera lens, attention is sharpened through a searching to focus on something and omit something else. It is about making choices and small discoveries in the vast landscape, the assemblages, and their mutual effects: in this case, from the concrete to the abstract. When Anne "fell in love" with the macro lens, it was the technological affordances through her actions and gaze that caused a vibration to happen with the materials and phenomena that she was photographing.

Materials in flow: from matter to transmateriality

Matter becomes performative, as the material of creative processes and work with digital technology and matter/materials are transformed into digital materiality through the camera lens. When digital expressions are transported out into space through the projector to merge with materials, objects and the physical materiality of the wall, we define this as a transmaterial (Leonardi, 2010; Munster, 2014) landscape. Working with the entanglements of physical and digital materiality allows for transformations and new becomings (Deleuze & Guattari, 1987). Transformations can occur as two- and three-dimensional, in movement, tempo, overlap and through projections onto objects. Through this engagement, an ongoing creative process takes place, in which photos from the exploration provide digital expressions that can be re-projected, themselves forming the basis for new photos, images, drawings and collages that, with sound and movement, become video and animation.

In our teaching project, we found that, through action, the room created frames, possibilities, refractions and inter-actions with materials, phenomena and digital expressions. The different textures of the room became performative when photos and video were projected onto the wall. The room's plan and lines were broken when photos and videos were projected onto, for example, a corner or the transition between the wall and the ceiling. In this way, various qualities of the space slipped into and became active components in the exploration and experimentation of transmateriality, and new qualities were articulated. The room as canvas (Hansson, 2016) and the room as language (Rinaldi, 2009) became performative as components in artistic and creative processes.

Toward a new creative and digital practice in ECE

Working in exploratory and experimental ways can open up new creative practices in ECE, where digital technology is integrated as a tool and medium that gives children the opportunity to produce and exchange knowledge through digital practice. In this way, the children's position is shifted from consumers to producers of digital expressions. Being creative in the exploration of digital technology is one of the goals of the Framework Plan, and the creative process can be seen as a mainstay in digital practice in ECE. In the educational project Material and Digital Landscapes, the students developed knowledge of the use of opportunities for creative work with digital technology, including

the use of touch devices. The interface of the touch device is intuitive and largely self-instructional. Therefore, in ECE, there is a danger of the staff leaving the exploration to the children. The Framework Plan states that the staff must "explor[e] creative use of digital tools with children" (MER, 2017, p. 45). An ECE teacher's professionalism is reflected in creating room for real exploration and interaction rather than letting children sit alone with applications where predefined goals dictate what can be followed. The formulations in the Framework Plan (MER, 2017) refer to learning wherein children are understood as explorative, sensing and reflective in their interaction and relations with materials and the environment. Using digital tools and media in working with spatial expression is a way of expanding and multiplying the possibilities of space and tools in everyday experience and creative processes. Emphasizing bodily and sensory inputs in digital technology opens up a richer understanding of what is experienced and learned. Exploring materials and materialities in transmaterial landscapes allows for bodily and sensory experiences with various materials and expressions, both physical and digital. In this way, exploratory digital practices can contribute to renewing and providing new ways of creation in collective learning processes for children and adults in the digital landscapes of ECE.

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Sense-making through Touch Interaction with a Picturebook App

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Abstract

Many picturebooks are published today as software applications (apps) for touch devices, presenting many opportunities for sensory experiences and interaction. A person's sense-making is embodied (or grounded) in sensory experiences and interactions, so these new technological opportunities will impact how they physically engage with and make sense of a picturebook app. However, few studies have examined touch and physical interaction with digital devices, a lacuna that is problematic in the digital age. This article poses the research question: How is touch interaction with a picturebook app facilitating or limiting sense-making? The conceptual framework for discussing this question embraces sensing, sense-making, and interaction. Two potential core paradoxes concerning digital touch devices and picturebook apps are introduced: a paradox of materiality and a paradox of interactivity. The award-winning picturebook app, Wuwu & Co., was studied through an in-depth explorative inquiry supported with diary questions. The inquiry identified several examples of how the picturebook app facilitated sense-making, including how its virtual materiality evoked past experiences of physical materials, how it evoked empathy in the researcher, and how the story could evoke particular reactions and emotions in the researcher. The inquiry identified limitations in the app related to possibilities of exploring, predetermined possibilities of acting, and how the device influenced sensory perception. The study indicates that the app provides rich opportunities for cooperation; however, this cooperation extends only to co-option, not to co-creation. These findings are useful for future users, facilitators, and those involved in future app development, because it suggests limitations in the medium and improvements that could enhance sense-making through active, co-creating, touch interaction.

Keywords:
Sense-making, picturebook apps, touch interaction, virtual materiality, emotions, embodied cognition, previous experiences.

Historically, picturebooks have been printed, telling stories through different kinds of interaction between images, words, and layouts. Today, many picturebooks are published as application software (apps) for touch devices, and some books are remediated as apps. A picturebook app can utilize technology to add living audio-visual effects to the storytelling and to facilitate interactions, such as virtual object manipulation, verbal commands, and physical movements of users. These new opportunities for physical interaction with picturebook apps can have a large impact on how a person physically engages with and makes sense of it, compared to a book. Physical interaction is key to a person's capacity to make sense of the world. Several studies in a range of areas, from art and craft science (Groth, 2017; Stenslie, 2010) to learning sciences (Sawyer, 2014, p. 24), have documented sense-making as one such grounded or embodied process, while neuroscientific knowledge has expanded and explained much of its biological basis (Bengtsson, 2013; Groh, 2014; Mason, 2011).

The role of touch and somatosensory perception for sense-making in new digital media has received less attention than studies in audio-visual cognition (Nicholas, 2010, p. 1). Some studies have explored literary experience, memory, and cognition while reading on screen as opposed to on paper (Mangen, 2016); others target the decreased material anchoring of memories on a screen as compared to the texture, size, and smell of a book page (Schilhab, Kuzmicova, & Balling, 2018, p. 2). However, knowing that cognition is embodied, this lacuna is problematic because our experience of things in our lifeworld is vitally dependent on and shaped by all our senses (Groh, 2014, p. 51ff). Touch may be a crucial part of this, as «more than any other modality, the sense of touch gives us the distinct feeling that reality — things, objects in the world — are, really, 'out there'» (Mangen, 2016, pp. 464–465). Thus, more studies are needed on how we make sense of virtual materiality, how touching digital interfaces limits or facilitates interaction, and which opportunities these devices give us to explore and make sense through touch. The aim in this article is to develop insider knowledge on this lacuna in order to generate a foundation for later studies involving children's sense-making with picturebook apps.

Conceptual Framework

Sense-making and Sensing

In this article, *sense-making* is understood as a person's active process of making sense of a situation or topic. It is a biological, socioculturally conditioned process of change whereby new and past experiences are combined (Sawyer, 2014, p. 11). This process of change is continuous: Humans are constantly experiencing and learning and thereby generating meaning in a physical, social, and cultural context. The individual's cognitive process is *embodied*, i.e., grounded in and shaped by the physical body's sensory experiences in an environment and their interpretation and assumptions of those experiences (Groh, 2014, pp. 205–216; Shapiro, 2017, pp. 1–6). Philosophically rooted in the perception phenomenology of Merleau-Ponty (1962), embodied cognition can explain why children engage in explorative actions—the purposeful, active seeking out of sensory input to enrich and support interpretation, to search for problems and find solutions (Fredriksen, 2011, p. 299).

The embodied basis of sense-making can be further explained by looking at the biological processes of sensing (Donoghue & Horvath, 2016, p. 2; Gulliksen, 2017). We receive *sensory information* through many types of sensory receptors located in our eyes, ears, and fingers, as well as through receptors, located throughout the body, that register pressure, texture, location, and position. This sensory information is unreachable for our consciousness until it is *perceived* as something. We perceive information as

vision, sound, smell, tactile perception, and haptic perception. Our vestibular sense of balance and equilibrium and our proprioceptive perception of our muscle length and force applied to a joint provide information about the body's orientation and position in the surrounding space (Groh, 2014, pp. 52–56). These sense modalities act together, making our sensory experiences multimodal: «We do not only see the environment with our eyes, but with the eyes on the head on the shoulders of a body that gets about» (Gibson, 1979, p. 279). For example, our visual stereo vision is created when light molecules, traveling in a straight line, trigger receptors in each eye's retina, which forms an image similar—in principle—to how an image is created in a pin-hole camera. This image is forwarded to the visual cortex as a brain map, a virtual representation of the outside world (Groh, 2014, p. 69f). Our somatosensory input is similarly mapped out: different areas in the brain make virtual representations of where our bodies are positioned and what sensory information they register.

However, if we were to become consciously aware of everything we hear, see, or taste, or of every light touch, hard touch, pain, or body position, we would be overwhelmed instantly. The same area in the brain that translates and transmits sensory input to the cortex, *the thalamus*, receives instructions on what to look for in the vast amount of sensory input, turning our attention toward one stimulus over another and biasing the sensory receptors to select one sensory stimulus and not another (Mason, 2011, p. 280). As such, we see only what we expect to see.

Such selective interpretation and attention to sensory input is a learned cognitive skill (Groh, 2014, p. 5) developed throughout the entire life span, through repeated interactions with the physical world, our emotional associations with them, and the memory of previous interactions: The way we feel toward something influences what sensory information we seek out and interpret; our implicit memory evokes and utilizes emotions, coloring our sensory experiences and focusing our attention on certain aspects; and our declarative, episodic memories organizes the memories as stories, linking recollected instances and facts with associations of sensory experiences (Purves 2012, pp. 698–699). Linked to the brain maps of space, memory is indexed, or situated, in previous experiences—for example, we remember more when assuming similar bodily positions or returning to previously visited locations in which we first experienced or learned something (Groh 2014, p. 199). Closely linked to memory and emotions, imagination is also a key factor in the sense-making process, as «each case of perception involves someone imagining what it would feel like to touch an object, grasp it with the hands, turn it over, bite it, smell it, and so on» (Gibbs 2006, p. 64). Together, these learned cognitive skills are the foundation for our sense-making, paving the way for future experiences and imaginings. We imagine, for instance, what an object will feel like before even touching it, or how it would look from behind. As a consequence of this, we can explain the phenomenon described by Merleau-Ponty (1962) in which tools, such as a blind person's cane, and the sensory information received through their use can themselves be perceived as a part of our perceptual field.

Sensing, Sense-making, and Interaction with a Picturebook App

Digital touch devices function as interfaces between users and software constituted as, e.g., images, sounds, and interactive features in a virtual three-dimensional space. Their main features are a pressure-sensitive screen, a wide range of visual, auditory, and interactive elements, and how they allow for use while moving or in different bodily positions.

A touch screen is paradoxical in that the user can touch objects without actually

touching them, and see objects that are not actually there. We refer to this aspect of touch screen devices as *virtual materiality*. While *materials* are tangible, and physical objects are made of materials, *materiality* refers to our perception, our experience, the representation in our brain maps, of these objects (Ingold, 2007, p.7). Virtual materiality, therefore, is an illusion. It has no physical properties. However, software provides stimuli that we interpret in much the same way as we would physical objects. What the user sees are representations of objects made by two-dimensional visual cues, such as color, haze, linear perspective, and occlusion. What the user touches is the software's pre-programmed responses to, for example, movement of the finger across the screen. Because, as discussed above, sensory perception builds on previous bodily experiences, emotions, and implicit and explicit memories, the user can experience the light and colors presented by the software program on a two-dimensional screen as something else—as, for example, a forest in a picturebook app. However, due to limitations (e.g., limited auditory frequencies in the device, two-dimensional visual cues used to construct an illusion of objects or space), virtual materiality will always be less rich than the materiality we perceive in a physical world. Put another way, the manipulation of a digital object on a touch screen is both an illusion and a tangible act—both virtual and material. This could present a *core paradox* in the embodied sense-making process with picturebook apps: the *material paradox*. In Stenslie's words: «The material paradox of virtual realities is that it is very material indeed» (2010, p. 128). The world in a picturebook app is not physical, but it is experienced that way via some physical conditions. In addition, our experience of time and space (the spatiotemporal) and the semiotic signs in digital media provide a structure to sense perceptions, while interpretation and thinking about the semiotic signs create meaning from these experiences (Elleström, 2011, p. 36). However, it then follows that we can only perceive virtual materiality in full if our previous experiences and brain maps are sufficient. Without relevant previous experiences, the two-dimensional illusion of a three-dimensional scene would lack information, leaving our perception open to errors or misrepresentations.

Interactivity has been emphasized as a key complement to the narrative flow of a story in a picturebook app (Nagel, 2017, pp. 2–13). In this article, interactivity refers to dialogue between users and audio and visual/spatial representations in an app. Examples include letting the user decide what or how something happens, features such as gyroscopes and accelerometers to respond to users' bodily movements, or, more indirectly, influencing users' perceptions by demanding specific time-consuming or procedural actions (Al-Yaqout & Nikolajeva, 2015, p. 5).

Interactions in picturebook apps can open for cooperation in a similar way to how computer game players interact with game storylines. Game-like elements are not a distraction, but are rather integrated as part of the total experience, and the «Increasing degree of interactivity leads into imaginative co-creation rather than merely making things jump, squeak, or shake on a screen» (Al-Yaqout & Nikolajeva, 2015, p. 7). However, this could present a *paradox of interactivity* between the app's pre-programmed features and narrative and the user's autonomy as «a co-creator of the narrative» (Nagel, 2017, p. 5). As noted above, sense-making requires future thinking, imagination, and action, and thus the co-creation aspect of a picturebook app is important, and potentially crucial.

In sum, digital touch devices and picturebook apps could present the user with two core paradoxes: the paradox of materiality, and the paradox of interactivity. These paradoxes likely influence the user's sense-making during interactions with the app.

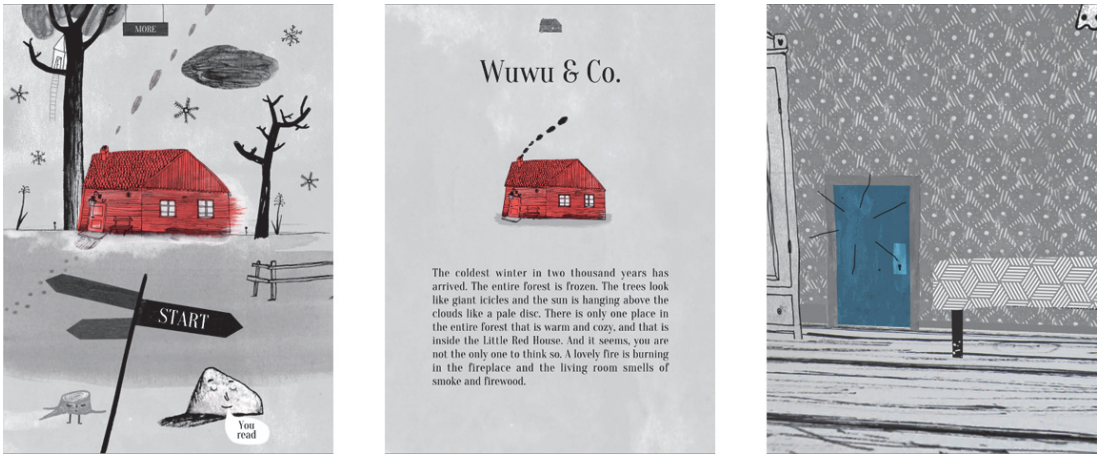

Figure 1. Illustrations from the Wuwu & Co. app

Below, we explore this by asking the research question: *How is touch interaction with a picturebook app facilitating or limiting sense-making?* We conducted an in-depth explorative inquiry on one case in particular—an award-winning picturebook originally published as an app, Wuwu & Co.

Method

Research Context

The picturebook app, Wuwu & Co. A magical picturebook (Figure 1), was developed as an original interactive virtual reality story for children by Step In Books (Helle & Slocinska, 2014). Choosing a children's picturebook as research context is useful, even though sense-making with picturebook apps is a general issue for both adults and children, because children are more avid readers of picturebooks. Wuwu & Co. is a fictional, illustrated world, complete with an integrated soundscape, narrator, and text. The narrative follows five creatures who need help during a cold winter. The narrative plays out in five different scenes, one for each character (Figure 2).

Figure 2. Five characters: Everett, Thit Maya, Wuwu, Pruney, and Storm.

These scenes are entered and explored through different types of interaction and game-like activities, many of them dependent on touch interaction—for example, *tapping* (to drive a basket), *shaking* (to make snow fall from a tree), and *gyroscopic movement* (to look up, down, and around in 360 degrees). When the device is horizontal, the app resembles a book. When it is held upright, it becomes a window into the world. Following the release, *Wuwu & Co.* won several awards for its innovative and immersive use of interaction. These qualities made the app a good context for addressing our research question.

Explorative Inquiry

The main method used for data generation was *explorative inquiry* (Dyrssen, 2010), which yields rich and complex data that can otherwise be difficult to obtain (Dyrssen, 2010, p. 230). Specific to this study, explorative inquiry yielded data on different types of action and expression, which were in turn used to infer knowledge of the sense-making process during the research. Integral to the method is its capacity to capture ongoing reflections and interpretations as they happen, as well as afterward. One such study, by Groth (2017), was used as a reference in developing our research design.

Author one, i.e., *the researcher,* generated the data. She completed the storyline in the app twice, from beginning to end. Author two completed the storyline as well, but did not participate in the explorative data generation. This two-author approach permitted both exploration from an insider perspective and a discussion of this exploration with an outsider to develop knowledge and mediate possible bias. Both authors contributed equally to the discussion and writing of the article.

Four types of data were generated:

a. *Pre-exploration diary questions,* answered verbally to elicit and guide the researcher's focus. Documented with video footage.
b. *Exploration* of the app. The researcher followed the app's storyline, making verbal, think-aloud accounts of experiences and interactions. No exploration guide was used. Documented with two video cameras: One headband camera to capture where the researcher looked, how she moved, etc., and one overview camera to capture the researcher's expressions and movements in the room. Both cameras also captured audio.
c. *Post-exploration diary questions*, answered verbally to capture the researcher's immediate experiential reflections. Documented with video footage.
d. *Data generated after the analysis: Thick descriptions* of selected instances were used to unpack thoughts, movements, and associations from the exploration and responses to the diary questions. Drawing on an art-based research methodology (Barone & Eisner, 2012), a poetic language was used.

The total amount of video/audio footage was four hours. Raw data from thick descriptions constituted approximately 5000 words. Diary questions and a full-text example of the thick descriptions can be found in the appendix.

Transcription and Analysis

All video/audio footage was transcribed, including facial expressions, gestures, movements, and verbal utterances, to document the richness and complexity of the experience. Bodily expressions were especially important to transcribe when the researcher was struggling to express her experience verbally.

A *first overview analysis* was made during the transcription phase, including the review of video and transcriptions, which was aimed at identifying instances of intense interaction by studying the researcher's actions and expressions. Cues included much activity/movement and/or surprise. The researcher

could use her insider understanding to identify these instances. Three scenes were selected for closer analysis. A *detail view analysis* of three selected scenes as written drafts was performed for thick descriptions through reflection during and after interaction. One scene was selected for further exploration and analysis, and was then developed into a finished poetic text, a thick description. A s*econd overview analysis* gave an overview of instances of interaction and experience.

The analysis concluded by identifying four main themes, each of which highlights important aspects: (1) material and materiality; (2) empathy and imagination; (3) interaction and relationships; and (4) boundaries for interaction. These themes are discussed below, with selected excerpts from the thick descriptions.

Analysis and Discussion

Material and Materiality

> *I look up and see animated snowflakes come toward me. The feeling of being outside on a dark and cold winter night comes over me. A dusting of snow. Quietly, it falls down. I know how this feels outside, in real life, what this physical material looks and feels like under my feet, when it hits my face. Snow against my skin. Soft and cold touch of snow. A forest swept in snow, the sound is like cotton, swept in, soft, muted. I am aware of my body in the physical room. I move my feet on the physical floor, like I do in the wintertime, checking if the surface is icy.*

This excerpt from the thick descriptions is from one instance in which materials and materiality were prevalent: The researcher moves the device over her head and looks into a virtual sky with animated falling snow. This evokes her previous experience of cold and melting snow touching her face in the physical world. The researcher holds the device and moves her body around its own axis, tilting the device up and down, then moves around in the physical world to do so in the virtual world. Thus, the researcher could, for example, follow a snowflake falling from the sky, which evoked somatosensory memories of stepping in physical snow and auditory memories of snow falling. This previously experienced materiality of physical snow even triggered the researcher to move carefully, checking whether the surface was slippery despite knowing it was a virtual, snow-covered forest. The scene evoked, through technological features, experiences of being immersed in a virtual forest by using virtual materiality and movement to evoke past experience of physical spaces. As such, virtual materiality affected the researcher through illusions that triggered previously generated somatosensory and visual representations in the researcher's brain map (Groh, 2014, p. 69f; Ingold, 2007, p. 7). This demonstrates the material paradox of virtual realities noted by Stenslie (2010, p. 128). Through the researcher's memories and imagination, the tactile feeling of snow was recalled, even when not in contact with it. The feeling of being surrounded substantiates how the sense of space is rooted in the combined interpretation of what we see and what we are doing (Groh, 2014, pp. 52–56). The experience of exploring the virtual forest demonstrates how touch, and the memory of touch, bridges the gap between the physical and the virtual. In a virtual context, many aspects rely on interactive features. Therefore, which past touch experiences the user carries are crucial to his or her experience with virtual materiality in an app such as *Wuwu & Co.* Virtual materiality is not tangible; however, it is still dependent on physical conditions, from which the device is made, the user's physical movements while interacting with the device, and the user's past experiences of interacting with and moving within the physical world.

Empathy and Imagination

> *I am standing in the living room in the WuWu house. Storm is standing in front of me. He is moving up and down trying to get my atten-*

tion. He has a sad expression on his face and big, expressive eyes. I can hear melancholy music being played in the background. What catches my attention is that I can see right through him, he is transparent. It's like I understand his vulnerability.

This excerpt is from one instance in which a strong empathic connection with the characters in the story is prevalent: The researcher experiences herself as being inside the house, together with the character Storm. She can see the living room's interior by tilting the device, and she can hear music playing and wooden logs crackling in the fireplace. She experiences the atmosphere as nice, with time flowing slowly whilst snow quietly falls outside the window. Her imagination draws upon previous experiences of similar situations and reinforces an emphatic connection with Storm—their shared experience of being safe inside. Storm's transparency leads the researcher to imagine herself as fragile, and when he later becomes opaque, she feels herself more protected by the surrounding forest. Sadness is interpreted both by the characters' eyes and the melancholic music. In the scenes, a character moving up and down is interpreted as worried or seeking attention. The emphatic impressions of the characters are not physical, but their movements and responses still give the impression they are actually there: a virtual materiality evoking emotions through interaction.

The ability to look around the living room via gyroscopic movement, the animated snow, the sound, and the characters' visual expressions give the researcher an experience and conception of time and space—the spatio-temporal modality mentioned by Elleström (2011, p. 36). This excerpt exemplified how the virtual world could evoke past experiences and empathy in the researcher. This capacity can be explained in terms of how memories are situated, as well as by how past experiences, emotions, and memories influence perception (Groh, 2014, p. 199; Purves 2012, p. 698–699). That is, in order to experience a virtual world on a two-dimensional screen as a three-dimensional space existing along a timeline, rich previous experiences are necessary. This is demonstrated in other examples from the researcher's exploration; for example, the timeless, in-depth, here-and-now experience of the muffled snowy landscape, similar to cases described by Al-Yaqout and Nikolajeva (2015). Further, this example demonstrates how the picturebook app can evoke imagination. This is problematic because sense-making requires the opportunity to imagine something not seen before, and to act on the basis of that imagining.

Interaction and Relationships

Storm invites me into his Snow Lantern Field. I am entering this world by touching him with my fingers.

This excerpt is an instance where the interaction between the researcher and the characters was prevalent. Touch and the sensorimotor activity of tapping the screen initiates a visual response in the character's movements: a virtual movement in a virtual world. The researcher is not actually touching the character, but the simultaneous response—the interactivity—gives the researcher a sense of connection. Even though the action of tapping in itself is seemingly mundane, touching is intimate. The immediate response of being invited into his world establishes a relationship through bodily memories of being in contact with persons. This relationship continues throughout the storyline, mixing Storm's story and the researcher's own experience and imagination. The researcher's role in the relationship varies from being a humble guest visiting «friends» in the virtual world, to experiencing it on her own within the app's limitations. This relationship and the invitation into Storm's world were experienced as meaningful.

The interactivity of touching Storm is a key example of how one can become immersed in his world (Nagel, 2017, p.13). In this way, the technology by which users

act in the world is important for their sense-making. The app is pre-programmed to tell one story and to evoke certain reactions and emotions. However, there is no *one* way to make sense of this story, and so it will be understood and experienced differently by each individual via their own pasts and new experiences gained through interactions, interactivity, and virtual materiality. The features in the app are thus active participants in guiding the user's attention, emphasizing what aspects to perceive while reducing others. The picturebook app's limitations lie in the predetermined number of possibilities to act, especially the ability to influence the technology and/or the narrative, as expanded upon below.

Boundaries for Interaction

> *I can see Storm's transparent relatives. They are standing closely together in a group. I touch them with my fingers, and they start shivering and call out for help, asking me to turn on the light. I find a lantern on the ground and by holding the iPad against the floor, I am collecting yellow colors and the light is turned on. The characters are no longer afraid of the dark and they become opaque.*

This excerpt is from one instance where interaction was prevalent: The user touches the characters, and they react by shivering and asking for help, spurring the user to interact with and help them in the virtual world. The user can find a virtual lantern in the virtual forest to light it by collecting yellow colors in the physical world with the device's camera. When one lantern is lit, the other virtual lights in the scene instantly turn on as well. The scene evokes a sense of urgency in wanting to help, and it stimulates the user's imagination to find the yellow colors. This is an innovative technological feature of the app, facilitating interaction between users and characters in the narrative, and the researcher's experience of being immersed.

The excerpt also highlights specific limitations for interaction. The sensory experience and sensorimotor interaction with the characters are limited to a first prodding, activating their shivering and calls for help. Touching the cold device to gather light is all users can do: They cannot put their hands on the characters' virtual bodies to hug them, and there is no feeling of warmth. The software's program also limits what can be used as a light source: The user cannot, for example, choose to light a bonfire to help the characters. Interaction with the scene is as such akin to following someone else's path, without the possibility of finding one's own path and creating new solutions.

Accordingly, these limitations exemplify the *paradox of interactivity*. Interaction with the app has boundaries in evoking experience and empathy, in creating opportunities for imagination and action. Given that sense-making is tightly connected to such experiences (Groth, 2017, p. 58; Nagel, 2017, p. 5) as well as to co-creation aspects (Al-Yaqout & Nikolajeva, 2015, p. 7), sense-making in the picturebook app can be said to be limited by these features. Interaction with the app is not a co-creation because of the lack of possibilities to act, to influence the technology and the narrative (Nagel, 2017, p.5). Instead, when entering the app, outsiders are *co-opted*, a term that refers to the process of adding members to a group that is already established. The users are co-opted into a virtual world, one that is exciting to explore within the set rules, but they cannot choose to go their own way.

Closing Remarks

The conceptual framework of this article indicates that a picturebook app offers specific types of sensory information that impact our perceptions and influence how our memories, emotions, and imagination are evoked—what sense we make when interacting with them. The explorative inquiry with the picturebook app *Wuwu & Co.* documented empirical examples of this. The study highlighted how the material paradox and the interactive paradox influenced sense-

making in touch interaction with the picturebook app. The virtual materiality could evoke past experiences of physical materials, it could evoke empathy in the researcher, and it could tell one story and evoke certain reactions and emotions. As such, the picturebook app facilitated sense-making; however, to experience such a virtual world on a two-dimensional screen as a three-dimensional space existing along a timeline, rich previous experiences were necessary. The inquiry also identified limitations in the interactions with the picturebook app related to the possibilities to explore, predetermined possibilities to act, and how the technology influenced sensory perception. As such, the study indicates that the app provides rich opportunities for cooperation; however, this cooperation only extends to co-option, not co-creation. This observation is important, suggesting that future studies should discuss whether this is a problem inherent in the technology, in the app medium, or if is this a problem that can be solved by app developers. Regardless, the knowledge of this paradox of interactivity is useful for future users, facilitators and those involved in future app development because it suggests limitations in the medium and improvements that could enhance sense-making through active, co-creating, touch interaction. In a future study of sense-making with *Wuwu & Co.* or similar apps, it would be relevant to include children as co-researchers. The picturebook app is aimed at young children, who experience the world differently than adults. Children also have other previous experiences, and as these were found to be crucial to sense-making in interaction with this app, studies including children would complement the current study. The analytic framework developed in this study presents both a theoretical framework and a methodological approach, which could be used to conduct such a future study.

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Appendix diary questions

Pre-exploration diary questions
What are you going to do and how?
What are the challenges of what you are going to do?
What are you thinking right now?
How do you feel right now?

Post-exploration diary questions
Did you manage to do what you intended?
Did your plans change? Why? How did you react?
What were the critical points?
What facilitated/hindered you in your process?
How do you feel now?

Appendix example of thick description from the scene: Storm and Snow Lantern Field

I am standing in the living room in the WuWu house. Storm is standing in front of me. He is moving up and down trying to get my attention. He has a sad expression on his face and big, expressive eyes. I can hear melancholy music being played in the background. What catches my attention is that I can see right through him, he is transparent. It's like I understand his vulnerability. I feel that I connect with him in a way, and he invites me into his Snow Lantern Field. I am entering this world by touching Storm with my fingers. I am standing out in the field surrounded by a magnificent dark forest. For several seconds, I am just standing there, looking into the forest, moving my body weight from the left to the right foot, holding the iPad in front of me. While I am walking with small steps in the physical room, I say with a careful voice: 'I can see into the dark in this forest. It's like I am entering this world'. I am just sensing. 'Oh, this is so beautiful'. I see the contrast of dark and light, black and white. I become aware of some of the trees in the dark and the way they are drawn. I can see traces from the drawing hand, from the sketching, it's like a thick pencil. I do scribbling with big movements in the air with my hand while I say: 'There is force in these lines'. I am moving carefully in the physical room, small steps, one at a time, I move the iPad in a circle around me, and this gives me the feeling of being surrounded by the forest, I stand out in the open field with the forest on all sides.

Storm is there with me, looking at me with his big eyes. I am holding the iPad over my head. I look up and see animated snowflakes come towards me. The feeling of being outside on a dark and cold winter night, looking up at the stars, comes over me. A dusting of snow. Quietly, it falls down. I know how this feels outside, in real life, what this physical material looks and feels like under my feet, when it hits my face. Snow against my skin. Soft and cold touch of snow. A forest swept in snow, the sound is like cotton, swept in, soft, muted. I sense this as a strong, embodied experience. I am aware of my body in the physical room. I move my feet on the physical floor, like I do in the wintertime, checking if the surface is icy. I feel a strong presence in the virtual cold and dark forest, standing in a warm and lit room inside a building.

The forest is like a room: It's protected and at the same time a bit scary. I want to be here in the fictional room, but it also gives me a kind of creepy feeling. I want to come closer to the forest. I am moving towards the trees, and I am moving my feet in the physical room at the same time as I move in the fictional room. I can see Storm's transparent relatives. They are standing closely together in a group. I touch them with my fingers, and they start shivering and call out for help, asking me to turn on the light. I find a lantern on the ground and by holding the iPad against the floor, I am collecting yellow colors and the light is turned on. The characters are no longer afraid of the dark and they become opaque. The transparency gives me the feeling of being fragile in this dark forest, and the opaque evokes the feeling of being safe. My mood is changing from excitement to this rare, mysterious feeling of presence and being, and to happy and good feelings.

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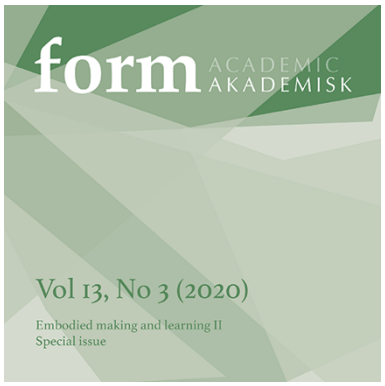
Publication III

Children's sense-making through exploration: Grasping physical and virtual materialities



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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.

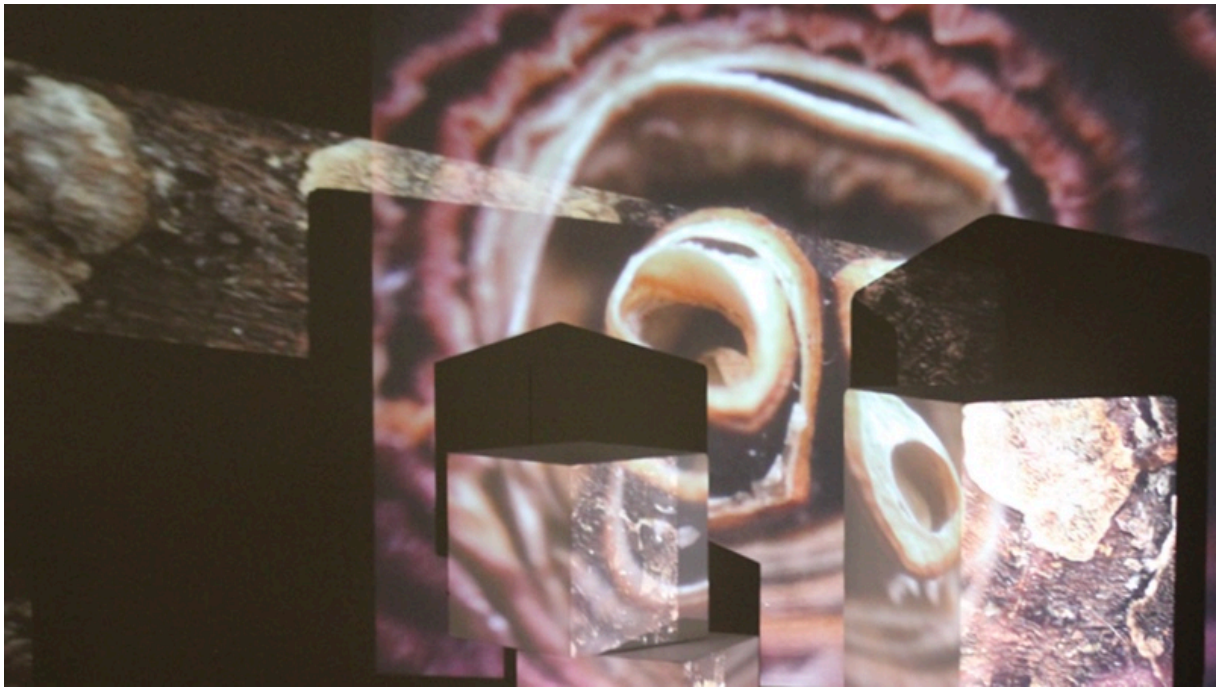

FIGURE 1. An artistic expression created in a room by projecting an image of a red onion into a physical environment consisting of material cubes. All photos in this article are by the author.

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.

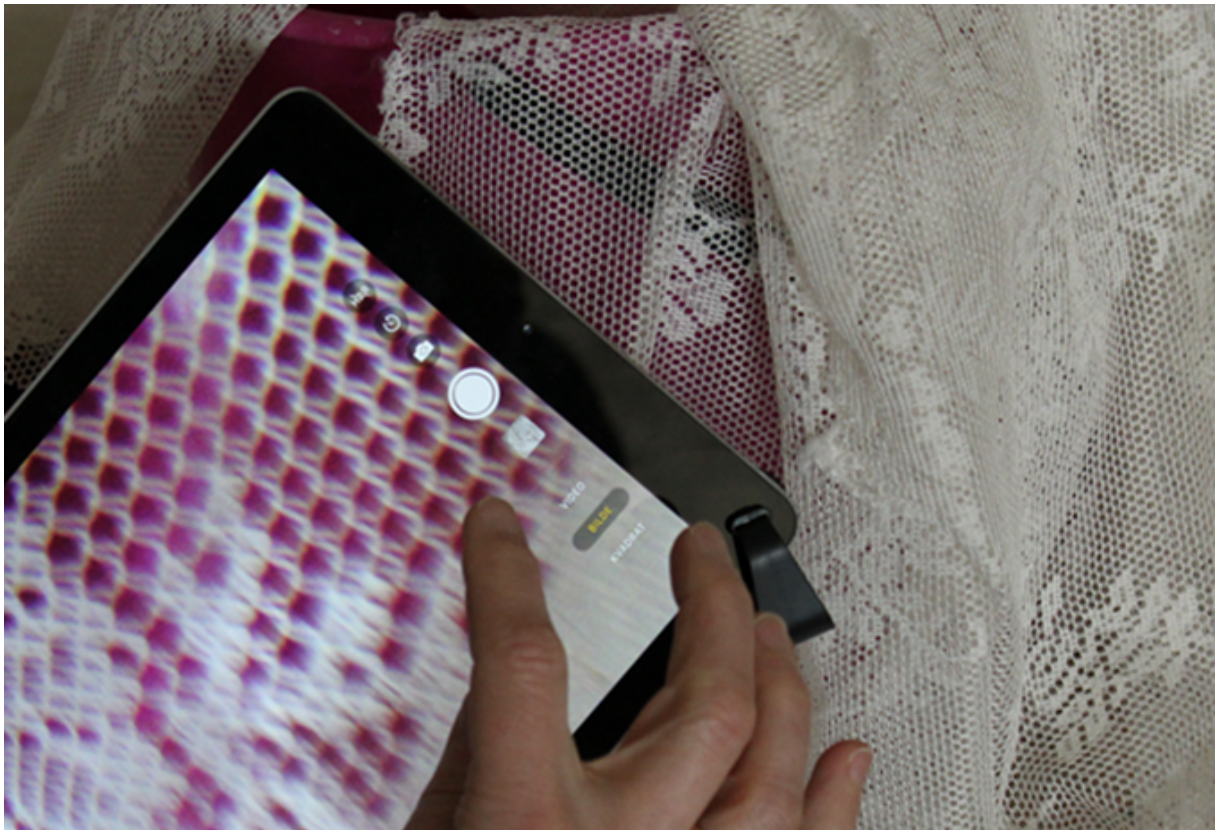

FIGURE 4. Digital technology can transform what we perceive

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.

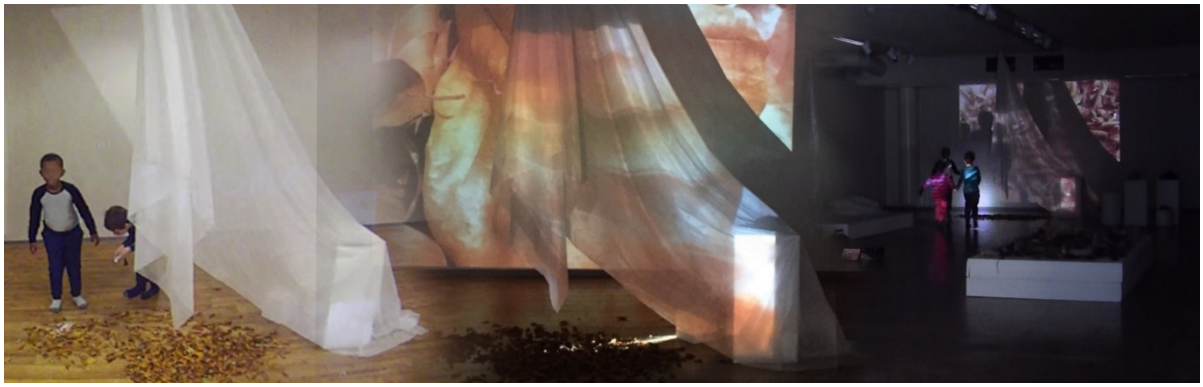

FIGURE 6. Interacting with the physical leaves and the projection.

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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Publication IV

Making sense of movement: A/r/tographic explorations of physical and virtual environments

Making Sense of Movement

A/r/tographic Explorations of Physical and Virtual Environments

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Abstract

A consequence of digital technologies' rapid growth is that learners experience virtual materialities to a greater extent than ever before in their environments. This can be described as a digitization of materiality, and it requires changes in how we use our embodied minds. The guiding research question in this chapter is as follows: How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations? The conceptual framework for discussing this includes embodied cognition theory and arts-based research approaches and two empirical studies. The first is a study of my own sense-making through touch interaction with a virtual reality picturebook app. The second is an examination of a group of children's exploration of physical and virtual materialities in an arts and crafts educational project. The central methods I used in these studies are a/r/tographic exploration, sensory ethnography, audio-visual documentation, and creating collages. This chapter is a retrospective reflection in which I interpret, understand, and learn from the methodological choices I made during these empirical studies. I analyze and discuss the research question via two main themes. In the first theme, I discuss how haptic visuality—embodied photos and video—are central in making sense of movement. Embodied photos (both my photos and the children's) and video can become another layer in developing an understanding of movement involving my haptic perception, memories, and sense of intimacy. Through this study, I discovered that haptic visuality is central for me as a researcher to making sense of a group of children's and my own movements in physical and virtual environments. In the second theme, I discuss how making collages is a reflective process for making sense of and expressing understanding of movements in different environments. I find collage-making to be a central part of my a/r/tographic exploration, and I recognize the act as a reflective process of developing understanding of movement and expressing my understanding and representations of haptic experiences. Theme two illustrates that collages are central to exploring and representing my sensorial experiences through surfaces and textures, all of which are linked to haptic visuality.

Keywords: a/r/tographic exploration, sensory ethnography, embodied cognition, movement, virtual environments, haptic visuality

Introduction

> *It was a cold cold winter day, and I was walking in the Norwegian forest. The entire forest was frozen, my cheeks were ice cold, and I could feel and hear the sound of crispy snow being squeezed under the weight of my body. Suddenly, I spotted a frozen small cabin ahead of me. I had never seen it before, at least not in the way that I saw it now. I was wading through the snow towards the old red cabin when a memory came to mind: walking through a virtual snowy landscape towards a little red house, and it was the coldest winter in two thousand years. . .*
>
> (The authors quote)

Digitalization requires changes in how we use our embodied minds (Mangen et al., 2019; Søyland, 2020). A consequence of digital technologies' rapid growth is that learners are now experiencing virtual materialities in their surroundings to a greater extent than ever before. This can be described as a digitalization of materiality (Browaeys, 2019). The purpose of this chapter is to discuss how I make sense of a group of children's and my own movements in physical and virtual environments, which I attempt to achieve using different arts-based approaches (Leavy, 2019) such as a/r/tographic exploration. A/r/tography merges a person's identities as an "a" artist, "r" researcher, and "t" teacher (Springgay et al., 2008). In cognitive science, sense-making is a central term within the enactive approach (Thompson & Stapleton, 2008). I use it to underline that in order to make sense of my own and others' experiences, I am dependent upon connecting new understandings to my past sensory experience with a particular focus on how movement and the visual are interrelated in said experience (Pusch & Lécuyer, 2011). I begin by describing the context of my study.

For the last ten years, I have worked as an artist, researcher, and teacher in arts and crafts early childhood teacher education (ECTE) at the University of South-Eastern Norway (USN). I emphasize a practice involving embodied, haptic, and sensational experiences through explorative processes in which materials play a central role (see Carlsen, 2015; Fredriksen, 2011). This practice highlights the importance of sense-making through a joint exploration of participants' surroundings. Norwegian ECE recommends that children have opportunities to explore and make discoveries using their entire bodies and senses (Ministry of Education and Research [MER], 2017, p. 22). In addition, children and adults are encouraged to explore and create together using different materials and digital technologies (MER, 2017, p. 45). My interpretation of this is that teachers should invite children into explorative sense-making processes of physical and virtual materialities through bodily movements, a practice that can be described as a material-digital practice (for examples see Søyland, 2020; Waterhouse et al., 2019). In recent years, I have grown increasingly aware of the importance of my identities as an explorative a/r/tographer (Irwin et al., 2019) through my interactions with both students and children in arts and crafts educational settings.

The practice I emphasize is founded on an epistemological understanding that our minds are embodied and shaped by the physical body's movement and sensory experience in an environment (Fugate et al., 2018, p. 1; Shapiro, 2017, pp. 1–6). In recent years, a renewed understanding of learning as an embodied process in interaction with the environment has emerged in the field of education studies (Bengtsson, 2013; Gulliksen, 2017). Sensitivity to the materiality of our environments is deeply ingrained in all living beings (Schilhab et al., 2018, p. 2). Materiality refers to our perception, our experience, and the representation of for example material objects (Ingold, 2007, p. 7). Developing an understanding of sensory experience in interaction with materiality is challenging because it involves tactile and haptic perception, hearing, smell, vision, and taste—modalities that act together to make our sensory experiences

multimodal (Søyland & Gulliksen, 2019, p. 3). Our senses operate in relation to each other (O'Regan & Noë, 2001, p. 940). In this way, vision must be studied in relation to movement. Thus, I investigate how arts-based methods shed light on a group of children's and my own movements in physical and virtual environments.

The desire to apply and develop methods that help us to understand our sensory experiences has grown among qualitative researchers in recent years (Jewitt & Leder Mackley, 2019; Pink, 2015). In addition, researchers in the field of children's learning with digital technology stress that studies would benefit from greater methodological diversity (Mangen et al., 2019, p. 242; Kucirkova et al., 2019, p. 3). One strategy for meeting this challenge, besides building on new knowledge concerning embodied cognition (Shapiro, 2017), is to use arts-based research approaches (ABR) (Barone & Eisner, 2012). Vist (2016) argues the need for an ABR dimension in exploring children's experiences. Some studies have taken advantage of visual ethnography as a tool (Carlsen, 2018), while others have been inspired by arts-based educational research (Fredriksen, 2011) in exploring children's embodied experiences with three-dimensional materials. In this chapter, ABR processes include my first-person experiences as an a/r/tographer and multiple ways of knowing, such as the sensory and the imaginary (Leavy, 2019, p. 5). As part of the ABR process, I draw upon ideas from sensory ethnography (Pink, 2015) as well as use audio-visual documentation.

The guiding research question of this study is as follows: *How do I make sense of a group of children's and my own movements in physical and virtual environments through my a/r/tographic explorations?* To investigate this question, I draw upon two of my own empirical studies (Søyland & Gulliksen, 2019; Søyland, 2020). In this chapter, movement includes both tactile and haptic experiences. In short, virtual environments is an illusion. In this study, virtual materiality is mediated via digital technology like a touch device or a projector (see Browaeys, 2019, p.4; Søyland, 2020, p. 2). We can experience them through vision, but not through touch, smell, or taste. To make sense of movement in virtual environments, humans use their experiential knowledge gained from moving in physical surroundings. When we experience virtual materiality or a virtual environment past our previous experiences of movement, we can re-enact material touch and other forms of sensory experience from the material world in this new experience (Søyland, 2020, p. 17). I use "I" in the research question to highlight that the understanding developed in this study emerged through my own personal experience (Bresler, 2006; Stake, 2010, p. 15). It is my understanding and experience of my own and a group of children involved in this study's movement that I present. I will now briefly elaborate on the conceptual framework of embodied cognition and arts-based research processes I use.

Embodied Cognition and Arts-Based Research Approaches

Embodied cognition theory explains how our interiority and knowing is enacted through our bodies (Noë, 2006). In short, each of us has a mind that is grounded in our senses and shaped by the physical body's experiences in an environment (Noë, 2006; Shapiro, 2017). In the context of this study, it is important to highlight that children understand their experiences in different ways than adults. This is because their brains are not fully developed, affecting, for example, their conceptual understanding (Wellsby & Pexman, 2014, pp. 2–3). Embodied cognition theory has developed in different directions. In addition to phenomenology (Gallagher, 2017) and psychology (Shapiro, 2017), it has especially been researched in the field of neuroscience (Schilhab, 2017) and enactivism in neuroscience (Noë, 2006). Gibson's (1979) theory of human–environment coupling explains how cognition is directly linked to a person's

ability to act and move, facilitated by opportunities the environment presents. Gibson created his theory long before the digitalization of learning environments; however, it provides a foundation with which to understand movements in virtual environments.

Cognition cannot be separated from the body—in our experiences, movements and senses are unified, and emotions are "ways of engaging with and make sense of the world" (Maiese, 2017, p. 231). This means that a group of children's and my own emotions, during movements in a virtual environment, influence the sensory information we perceive in that setting; this is because our experiences are affected by our attention, preconceptions, what we like, and what we dislike. Memories are also key in developing our understanding of movement because they relate to our embodied knowledge and past experiences. Memories are multi-sensorial—"we process and store memories about events from how they are sensed, experienced, consciously understood, and emotionally felt" (Schilhab et al., 2018, p. 2). Our memories are thus a core part of our sensing—they direct our attention in experiencing new sensory information, and they are a basis for understanding and making sense of new information. Implicit memory uses emotions without our conscious awareness when we, for example, move; this colors our sensory experiences and shifts our attention toward specific aspects of what we sense (Purves et al., 2012, pp. 698–699). Declarative memory, or what we can remember consciously, colors our emotions in episodic memories and includes sensory experiences and details that we can recollect (Purves et al., 2012, pp. 698–699). Our embodied knowledge can be re-enacted through our perceptual and sensory systems and evoke past experiences of tactile sensation and movement (see Fugate et al., 2018, pp. 1-2). Memories are thus a core part of developing an understanding of movement, both targeting attention when experiencing new sensory input and providing a foundation to make sense of our own and others' experiences.

I deemed ABR to be relevant for this study particularly because it is a process-oriented style of research (Leavy, 2019, p. 9). ABR corresponds well with the explorative material-digital practice described in the introduction, and it involves the explorative body-space perspective in an environment, integrating all the senses anchored in bodily experience (Dyrrsen, 2010, p. 225). ABR can facilitate new understandings by describing, exploring, expressing, and discovering new terrain (Leavy, 2019, p. 9; Pink, 2015, p. 160). It can extend our knowledge beyond the limiting constraints of verbal communication and develop new insight in experiential knowledge (Barone & Eisner, 2012, p. 1). I understand a/r/tography and sensory ethnography (Pink, 2015) to be two interwoven perspectives within the ABR methodology (Barone & Eisner, 2012). Further, I frame sensory ethnography as an embodied form of ethnography that moves beyond the text and the visual to experiential knowledge (Pink, 2015, pp. 28–29). Both a/r/tography and sensory ethnography involve participation research, which is central in this study.

Visual Methods

I now describe the *arts-based visual methods* I used to develop insight during this study, which can include a wide range of forms such as photos, video, and collages, all of which I use in this study. "Arts-based visual research is gaining attention in the social and human sciences as qualitative researchers increasingly consider the use of images in research" (Holm et al., 2019, p. 311). The core of making sense of a visual experience lies in sensory qualities like movement (Rose, 2016, p. 34). "Participatory photography" (i.e., a researcher's photos) is often used in qualitative research; it is also a common way to engage children in research (Clark, 2014, pp. 200–203; Holm et al., 2019, pp. 316–317). Clark (2014, pp. 200–203) describes how children's participatory photos in research can be a way to include their views and experiences. She frames children's participatory photos as part of what she terms a "mosaic approach" (Clark, 2014). MacDougall (2005, p. 3) uses the phrase "corporeal images" to describe how photos are images

of the body behind the camera and how they "refer back to the photographer at the moment of their creation." Photos and video cameras can be considered as part of the ethnographer's movement and engagement in a context (Pink, 2015, p. 125)—they involve forms of bodily and sensory engagement that bring together vision, sound, and tactile and haptic perception (Pink, 2015, p. 118). Others discuss how video from cameras such as a headband camera allows the researcher to gain insight into experiences like movement, speed, framing, and sound (as captured by the wearer) (Harwood & Collier, 2019, p. 54). In such settings, it is important to acknowledge that video is a source of potential data (Erickson, 2006, p. 178); however, it is through the researcher's processing that video becomes data. Video cannot record emotions, movements, taste, or smell in the same way as it records sounds and images (Pink, 2015, p. 125). In the context of my study, it is now useful to turn to *haptic visuality*. In *The Skin of the Film*, Marks (2000) emphasizes how memories of embodied experience like haptic perception can be evoked through the medium of film (p. 162). From the embodied cognition perspective, this is described in the way that previous memories of tactile and haptic experiences can be triggered by visual feedback, creating the illusion of a haptic experience (Pusch & Lécuyer, 2011, p. 57). In this way, haptic perception is different from a physical haptic experience.

A new method within ABR is the artistic technique of collage (Scotti & Chilton, 2019, p. 355). Generally speaking, collages are made by cutting elements out of photos, drawings, and materials (e.g., textiles and/or paper) or by choosing existing objects (e.g., ready-mades) and attaching them to a surface to create a composition. A collage can also be made digitally by using a software program or combining the material and the digital. In ABR, the aim of making collages to conceptualize ideas and reflect upon them during the research process (Scotti & Chilton, 2019, p. 360). A collage can evoke, give access to, or foster sensory experiences and embodied knowledge both for the researcher (in the making process) and for the person viewing the collage (Scotti & Chilton, 2019, pp. 359–361).

Research Setting

This study is based on my experiences and reflections during and after the research processes contained in several of my empirical studies: "Sense-Making Through Touch Interaction with a Picturebook App" (Søyland & Gulliksen, 2019) and "Children's Sense-Making Through Exploration: Grasping Physical and Virtual Materialities" (Søyland, 2020) (see Figures 1 and 2).

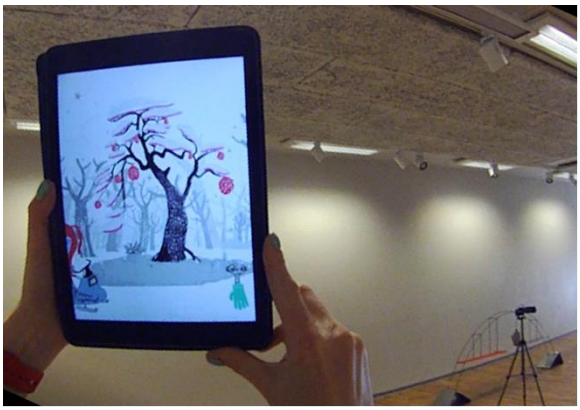

Figure 1: A photo from my movement and interaction with the virtual picturebook app.

Figure 2: A photo of two children exploring virtual materiality through a camera lens on a touch device.

This chapter describes my retrospective reflections intended to help me interpret, understand, and learn from my methodological choices and experiences from these two empirical studies. My understanding has also grown through sharing and discussing my

experiences from these studies within a national and international arts-based research environment. In the following, I refer to the studies as the "MSM study" (Søyland & Gulliksen, 2019) and the "CSM study," (Søyland, 2020) respectively. The MSM study is an examination of my own sense-making through touch interaction with the virtual reality picturebook app Wuwu & Co.'s "A Magical Picture Book" (Helle & Slocinska, 2014). When the touch device containing the app is held upright, the screen becomes a window into an illusional three-dimensional world (see Figure 1). The narrative in the story contains different types of interaction like tapping (to initiate a programmed movement on the screen) and gyroscopic movement (to look up, down, and around [360 degrees]). In the CSM study, I invited a group of young children and their ECE teacher to enter a large-scale project room that I facilitated; I invited them to explore the room using different digital technologies (iPads and projectors) and physical materials (e.g., thorny twigs and a buck skull) (see Figure 2). The study examined the children, the ECE teacher, and my joint exploration of physical and virtual materialities.

In both studies, I was positioned as a/r/tographer (Irwin et al., 2019), related to ideas from the sensory ethnography (Pink, 2015) and used visual methods such as audio-visual documentation. I wore a headband camera during the explorations; I also placed an overview camera in one corner of each room. In the MSM study, I took photos as part of my process of developing my understanding of materiality and movement. In the CSM study, I took photos when something interesting happened and I had the opportunity. I also included the photos the children took in the CSM study during the joint exploration as documentation. My goal in transcribing the video and analyzing the empirical data was to capture rich and complex sensory experiences through, for example, facial expressions, gestures, and movements. In both studies, I developed thick descriptions (Stake, 2010, p. 49) of the analyzed empirical data, and I made digital collages in the software program Procreate. In the analysis and discussion presented in the next section, I focus on two main groups of themes: 1) haptic visuality—here, embodied photos and video are central in how I make sense of movement; and 2) creating collages—a reflective process I use to make sense of and express my understanding of movement in physical and virtual environments. In the context of these studies, it is important to highlight that I present *my* understanding of the children's and of my own movement. As an a/r/tographer, I can never fully understand others' experiences—I can only imagine, suggest, and try to understand what characterizes them.

Analysis and Discussion

Haptic Visuality: Embodied Photos and Video are Central in Making Sense of Movement

Here, I discuss how haptic visuality, embodied photos, and video are central in making sense of movement. Haptic visuality explains how our senses are interrelated and how previous haptic experience can trigger visual feedback and create an illusion of, for example, movements (Pusch & Lécuyer, 2011, p. 57). This concept is central to my discussion, as I took photographs, used a headband camera, and used an overview camera in both empirical studies.

I started this chapter by describing becoming aware of how I connected my sensory experience of walking through a physical landscape to my past experience of "walking in a virtual landscape." Wuwu & Co, the characters in the picturebook app, live in a red house in a winter world that the story describes as being the coldest it has been in 2,000 years. In the MSM study, I was in a process of making sense of my own movements when I was interacting with this virtual magical snowy forest. During this time, I moved in interaction with the touch device in a physical room while I was "inside" and "moved" in the virtual. The headband camera (attached to my head) captured my bodily movements from my perspective (this use can be characterized as a subject camera). I was completely immersed in this virtual snowy forest and

only partially aware of my own movement in the physical room. When I later studied the video from the headband camera and began my analysis, I could follow my own movements through the embodied video. Here, I could understand small details in my movements, like hesitating, my breath and bodily sounds, and how I was bending my head down to look at my own feet for a second when I was entering the virtual forest with a slippery surface (for example). I discovered that I walked carefully in the physical room when the surface "was icy and slippery" in the virtual environment. In line with Pink's (2015, p. 125) description of the researcher's body and digital technologies, the digital recording device became a part of my embodied mode of engagement and participation. Video from the camera attached to my body presented me with important information for understanding movement in interaction with the material world and the illusionary three-dimensional virtual world. In the process of making sense of the video from this interaction, especially haptic visuality (Pusch & Lécuyer, 2011, p. 57) became central in developing my understanding.

Studying the picturebook app, I followed the storyline from the beginning to the end twice. In the weeks that followed and during part of my analyzing process, I became particularly aware of my tactile and haptic perception and my bodily movement in interaction with physical landscapes covered by snow. During walks in non-virtual, physical landscapes, I used my camera to photograph snow in various forms. This was part of my a/r/tographic exploration seeking understanding of how I make sense whilst moving in physical and virtual environments. I became preoccupied by the feeling of walking on icy surfaces—the sound of ice being crushed under my feet, and I photographed such surfaces. I also became absorbed by the feeling of being surrounded by physical snowy forests—the feeling of being "wrapped in" and how the physical environment evoked certain emotions, like feeling safe. In line with Maiese (2017, p. 231), I found my emotions to be a central part of my embodied knowledge walking in these landscapes. I used the camera to take photos of my physical surroundings as these emotions emerged. The photos became important in the process of looking back to delve into these moments to try to make sense of them. These photos also became the starting point of my artistic process of making collages, which I discuss in the next section. My photographing while moving in outdoor terrain became a central part of my process of developing understanding of how moving in physical environments bridges one's understanding of the material and movements with virtual materiality and virtual environments. I further elaborate upon this at the end of the section.

During the exploration in the CSM study I was present in the moment close to the children, observing, playing along, positioning myself in the room, and finding the right angle and lines while taking photos. MacDougall (2005, p. 3) describes how photos are corporeal. In this study, I prefer to call them "embodied photos" because they are taken with a mobile hand-held camera by me, a subject with an embodied mind. During both studies, the camera became like an extension of my body through movement in both the outdoor and indoor environments. In the CSM study, I am behind the camera seeking and selecting important instances of the children's movements. The photos are expressions and are part of what I have felt and sensed in these moments; they are glimpses of my understanding during our joint explorations. In this context, the photos become expressions of my body behind the camera, the children's bodies in front of the camera, and the interaction between our bodies in the environment. I found that such photos can represent important sensory information in developing understanding of movement, especially in studying a context with virtual materiality that contains less sensory information than does a physical materiality. It is my embodied photos from these moments—and while analyzing the data material, it is my memories, emotions, and sensory experiences from these moments—that I am connecting and recalling during the process of developing my understanding. An example of this can be seen in Figures 3 and 4, where I grasped some of the child's movements and emotional and bodily expression in interaction with a physical and

virtual environment. This is an example of how the virtual materiality initiated the child's movements.

Figure 3: A child's movements in a physical and virtual environment.

Figure 4: Another photo of the child's movements and bodily expressions.

I also included the children's "participatory photographs" in this study (see Clark, 2014, pp. 200–203; Holm et al., 2019, pp. 316). Their embodied photos were important for developing an understanding in conjunction with my memories from being present in the explorative setting. The different parts of the empirical data can be approached as a form of data triangulation. The children's photos provided me with nuanced information about their movements and their attention. I understand this to be what Clark (2014, pp. 200–203) describes as a mosaic approach that includes children's views and experiences through photos in a research setting. The photos presented me with glimpses of tactile and haptic information about their attention, movements, and material engagement. Their photos showed, for example, that they explored the buck skull in many ways, such as moving it in different directions (see Figure 5). In addition, the photos showed how they moved around the buck skull (see Figure 6) or moved in interaction with another child and the materiality of the environment (see Figure 7).

Figure 5: A child's photo moving close to the buck skull to explore its materiality.

Figure 6: A child's photo moving around the buck skull.

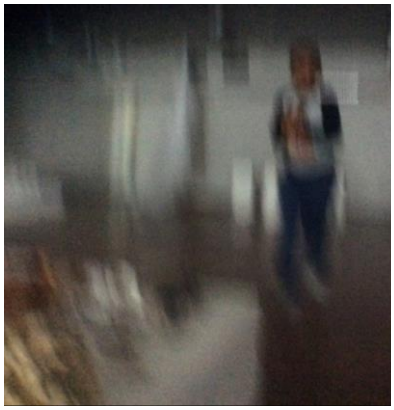

Figure 7: One of the children's photo in movement with another child and the materiality of the environment.

Figure 7 is an example of a photo that provides information about the body behind the camera. Used in my analysis, these photos allowed me to study such "frozen moments." It could have been fruitful to have conversations with the children about their photos after our joint explorations. I will consider doing this in future work.

MacDougall (2005) describes photos as corporeal. I understand both photos and video to be embodied and referring back to the person behind the lens. Video from mobile phones, hand-held cameras, and video cameras attached to the body contain more sensory information than photos. This is because videos are audio-visual, capturing the movements from the wearer and are photos in motion. In contrast, the video from my headband camera does not contain my conscious decision (or the children's) to take photos at specific moments that I understood to be important. A photo is an expression of a frozen moment in time and space, and the specifics of that can contain important information in a process of developing insight into movement. In both the MSM study and the CSM study, the headband camera captured a kind of rhythm—a close-up that was near to my own sensory experience. This is in line with how Harwood and Collier (2019) describe the features of such technologies. The headband camera became like a part of my body and captured embodied video near my sensory experience and movement—this can be understood as an embodied perspective. In contrast, the video camera in the corner of the room captured an overview of the interactions, similar to an objective bird's-eye view, from the outside and represented a more general recording of movement. During the analysis, both these angles, the subjective and objective cameras, were important—they enabled me to commute between the close-up and the overview whilst developing my understanding.

In the CSM study, the headband camera captured where I looked, my own and the children's verbal utterances, sounds of movements, the manipulating of materials, and how the children and I reacted and moved through joint exploration. In one instance, a boy spotted a thorny twig laying on a podium in the large-scale project room. The boy expressed excitement while he was moving toward the thorny twig and when he sat down by it. When he slowly leaned his body forward and touched the tip of the thorny twig, I connected his touch to my own sensory experience. Studying the embodied video from this instance, I could study the boy's movement and how I moved in interaction with him. In this instance, I could observe the video footage of the boy's bodily language and movement over and over again to understand more of his experience. This is in line with Harwood and Collier (2019, p. 354), who emphasize how visual material can capture more of the nuances of children's experiences. The boy's facial expression, the sound of joy he made, and the way he moved his body, hands, and feet were central to me understanding his movement. In this situation, my past experience of the material and environmental affordances allowed me to develop understanding (Gibson, 1979) of the boy's experience. My understanding was colored by my implicit and declarative memory (Purves et al., 2012, pp. 698–699) and affected by my identities as a/r/tographer. In the process of analyzing these instances, an episodic memory appeared that included a suite of sensory experiences and details from my childhood (see the following quote and Figure 8).

> *I am walking toward a hairy cactus in my home. I stop, and I am standing in front of the window, watching it on the windowsill. It is a grey and foggy day accompanied by rainfall leaving raindrops on the window. My attention is directed toward the hairy cactus. I am moving my hand in its direction. It looks so soft; it has long, gray, thin hair. It's as if it's screaming at me: Touch me! I've touched it before; I know it leaves small, painful needles in my fingers. I can hear my mother in the background. She's warning me: Don't touch it; you know what will happen. I'm excited. My body is trembling. It looks so inviting, I cannot help myself. Gently, I move closer, and I lay my hand on it.*

Figure 8: Photo of a hairy cactus (Author's photo).

This memory imprinted me with how I, as a child, moved toward, sensed, emotionally felt, and consciously understood the hairy cactus. This is in line with how Schilhab et al. (2018, p. 2) describe how we store memories. As an adult, it is impossible to experience as a child. However, in the present research context, my past experience—especially the embodied video—became central in developing an understanding of the child's movement. I looked back to my own childhood to reflect and allowed my own emotions to be a part of my new understanding. The video footage together with my own observations and memories encountered and comprehended as Pink (2015, p. 168) describes creates a sense of intimacy and awareness of touch experience. Later on, a group of children explored a virtual thorny twig that was projected onto the wall in the large-scale project rom. During this instance, a boy was pretending that he could pull the two-dimensional virtual thorny twig off the wall. I understand the boy was using his past experience of haptic perception (handling a three-dimensional physical object) when he moved and pretended that he could pull the virtual thorn off the wall. The child's movements affected me, having similar experiences from moving my own body (e.g., holding my arms around a thick tree trunk, leaning my body back to try to pull it up by the root or to move and drag something heavy like a tree trunk after me). Such experiential knowledge became part of my understanding of what characterized the boy's experience of movement within the virtual materiality in the environment.

When I planned the CSM study, I used my past experience and imagination of the affordances of the materials, environment, and digital technologies. However, the children did things I did not expect and to which I had to respond. Accordingly, we made sense of and learned collectively through our joint exploration, which became an important part of my understanding of what characterizes their movements and experiences. Irwin et al. (2019, p. 37) suggest that the "t" in a/r/tography should also include the learner. My interpretation is that in this case, both the children and I were learners. In this relational interaction, the children, myself, and the surroundings were involved. This power of relationship—a space where I also can learn from them—requires I pay attention to the children's movements, senses, interests, engagement, and expressions. It exemplifies how important experiential knowledge and the senses are in the process of understanding children's sensory experiences in an educational research context. The instances described in this section underline how, as a researcher, my knowledge of haptic visuality is central to making sense of a group of children's and my own movements in physical and virtual environments. This also illustrates how embodied photos and video can be important supplements to the sensory, embodied way of knowing through participation research.

Making Collages: A Reflective Process to Make Sense and Express Understanding of Movements in Physical and Virtual Environments

In this section, I discuss how making digital collages can serve as a process to make sense and express understanding of movements in physical and virtual environments. I discuss two examples from the MSM study and one from the CSM study. In the MSM study, I manipulated my own photos as part of the collage-making. I used the software program Procreator to both manipulate and compose with the photos. I processed my own experiences and emotions of moving in physical and virtual environments during this making process to detect connections, similarities, and differences in moving in such surroundings. The making of collages in this study was first and foremost a part of my a/r/tographic exploration and reflective process. This is in line with how Scotti and Chilton (2019, p. 360) describe collage-making as part of a researcher's process. In the first example from the MSM study, I reflected on the feeling of walking on icy and snowy surfaces (see Figure 9).

I studied my own haptic feelings and imagination of walking on snow on a really cold winter day and the sound of snow crushing under my feet while moving on such surfaces. Examples of what I did in the making process of this collage (Figure 9) were to add colors to create contrast with the texture of the frozen ice crystals, use tools to sharpen the texture of the illusional icy surface, cut out parts of the photos, and adjust the light in these spaces. This was part of a process of studying my own sensory experience of physical and virtual materialities of snow. The texture of this collage (Figure 9) is contrast-filled, and the snow crystals stand out like sharp spikes within the texture. In the making process, I also worked with collages that had a more soft and sensitive expression. In the process, I reflected on how the physical three-dimensional forest felt under my feet whilst I was moving. I imagined the sound of moving through physical environments wrapped in snow. I imagined it to sound like cotton—soft and muted. Moving in the virtual forest, I had to imagine the feeling of snowy and slippery surfaces and their textures.

Figure 9: A digital collage of a snowy surface.

When I was moving in the virtual environment, my movements were accompanied by a soundtrack of wind and of feet moving through the snow that did not correspond with my own movements. However, in my experience of moving through the virtual environment, my attention was shifting from experiencing the sound from the app to my own imagination and bodily feeling of moving through a snowy forest with a soft sound like cotton was present. My past experience and imagination of physical snowy forests was a bridge to my experience and understanding of moving through the virtual environment. I understood the process of making collages and the expression of a collages to be largely about sensorial information through surfaces and textures linked to haptic visuality. In this process, my interrelated senses of sound, movement, and material surfaces were a central part of my sense-making process. In the second example in the MSM study, I examined my emotional aspects of moving in physical and virtual snowy environments (see Figure 10).

Figure 10: A digital collage of one of my explorations of developing understanding of moving in physical and virtual environments.

My interaction with the picturebook app evoked bodily feelings and emotions connected to physical environments. While moving through the dark virtual forest, I meet some creatures that were afraid of the dark. I emphatically connected with the virtual characters of the story and to the feeling of being afraid inside a dark forest. As a contrast to these feelings, I felt safe and protected while I was moving through the virtual forest during daylight. The experience evoked good feelings—when I moved my body 360 degrees around in the physical room simultaneously as I moved 360 degrees around in the virtual forest, I described this as a beautiful and magical experience. I studied this different and my ambivalent feelings of moving through a physical and virtual forest covered by snow through the making process (see Figure

10; see also the digital collage on the title page). In these collages, I especially worked with colors, texture, lines, and contrasts and included an element/layer of a photo of myself. Specifically, I placed a photo of my own shadow near the lower left corner of the collage to illustrate the feeling of being small inside a large forest. I made a clearing near the middle of the collage; this was part of my reflection of the feeling of moving at a fast pace through the forest to leave the forest before it grew dark. The black shape (a separate layer) in the upper left and right corners illustrated the darkness that arose, which felt as a threat. I also positioned the trees as diagonal lines, which might give the feeling of something disturbing. During this reflective making process, I developed an understanding of how I connected emotions from three-dimensional physical forests and from social contact with humans (connected to the virtual creatures) to the experience of the three-dimensional virtual environment.

My collage-making in the CSM study was different from my collage-making in the MSM study. First and foremost, there was a significant difference between expressing my own experience of movement (MSM study) and expressing my understanding of the children's movement (CSM study). Making collages of children's photos from our joint exploration also raised ethical considerations about representation of experience. In the MSM study, the making process was mostly about my own reflective process to study my sensory experience and emotions during my movement. In the CSM study, I made a more conscious choice to create collages to express my understanding of children's sense-making in specific instances of moving in physical and virtual environments. The instance expressed in the digital collage (see Figure 11) occurs after a group of children and I had explored a physical buck skull in different ways.

Figure 11: A boy uses his imagination to create a world in which he explores different materialities through movement.

The children had explored the buck skull by moving close to it, around it, and by touching it with their hands. When one of the children's photos of the buck skull was projected into the room, a boy entered an imagined world where he pretended to be a kind of scary ghost moving in the physical and virtual environment. During the process of making collages, I made artistic decisions using visual features like lines, contrasts, and rhythm in similar ways as during the act of photographing (see the collage in Figure 11). I observed the boy playing and moving within a physical hanging cloth with a photo of the buck skull projected on for a long period of time. In the collage, I assembled four photos from this event. Each of the photos represents different movements of his interaction. By composing and tagging photos together, I give the viewer the opportunity to dwell in "slow-motion" with nuanced changes in movements of the boy inside the hanging cloth. I used a smudge brush tool to soften the edges between the four photos and to connect them. My intention with this collage was to express some of my understanding of the boy's emotional and haptic experience whilst moving in a physical and virtual environment. The collage portrayed my understanding of the child's movements in this environment. I understand collage-making to be a central part of my a/r/tographic exploration seeking insight into movement in physical and virtual environments.

Closing Remarks

The study presented in this chapter illustrates my attempts to make sense of movements through a/r/tographic explorations in physical and virtual environments. Embodied cognition theory has provided me with a useful theoretical framework for developing my understanding of movement within different environments. I have analyzed and discussed the study via two main themes. In the first theme, I discussed *how haptic visuality—embodied photos and video—are central in making sense of movement*. Embodied photos (both my photos and the children's) and video can become another layer in developing an understanding of movement involving my haptic perception, memories, and sense of intimacy. Through this study, I discovered that haptic visuality is central for me as a researcher to making sense of a group of children's and my own movements in physical and virtual environments. In the second theme, I discussed *how making collages is a reflective process to make sense and express understanding of movements in physical and virtual environments*. Through the process of making digital collages, I developed understanding of connections, similarities, and differences of movement in physical and virtual environments. Collage-making was a central part of my a/r/tographic exploration seeking understanding of movements. I recognize collage-making as being a reflective process of developing understanding of movement and as being expressions of my understanding and representations of haptic experience. I have found collages to be central to exploring and representing sensorial experience through surfaces and textures as linked to haptic visuality.

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9 Appendix

9.1 Letter to the Parents and Consent Form

9.2 Confirmation from the Norwegian Centre for Research Data (NSD)

Lovise Søyland
Høgskolen i Sørøst-Norge
Postboks 235
3603 Kongsberg

Kongsberg 08.02.2018

Til foreldre og foresatte til [redacted].

Informasjon om deltagelse i forskningsprosjekt

Siden november 2016 har jeg arbeidet med doktorgradsprosjektet *Sense-making i interaksjon mellom fysisk og digital materialitet. En studie av utforskende og skapende handlinger.* Jeg er doktorgradsstipendiat i visuelle kunstfag ved Høgskolen i Sørøst-Norge, Institutt for estetiske fag. Jeg er tatt opp på doktorgradsprogrammet i pedagogiske ressurser og læreprosesser ved Høgskolen i Sørøst-Norge.

I perioden 12.mars -13.april 2018 skal jeg gjennomføre en studie der barna deres inviteres til å bli medforskere i prosjektet. Formålet med studien er å undersøke hvordan de eldste barna (5-6 år) undersøker og utforsker ulike materialer og digitale verktøy i skapende prosesser. Studien er en del av mitt doktorgradsprosjekt som skal ferdigstilles tidligst høsten/vinteren 2020/2021.

Bakgrunn og formål

Barns læringsmiljøer endres raskt fra fysisk til virtuelt og fra fysiske materialer til berøringsskjermer. Formålet med forskningsprosjektet er å undersøke hvordan barns sense-making kommer til uttrykk i skapende handling mellom fysisk og digital materialitet. Prosjektet er finansiert av Høgskolen i Sørøst-Norge. Ansvarlig veiledere for mitt prosjekt er professor Marte Gulliksen og førsteamanuensis Biljana Fredriksen ved Høgskolen i Sørøst-Norge.

Hva innebærer et eventuelt samtykke?

Studien innebærer at barnegrupper på tre inviteres til Campus Notodden ifølge med en ansvarlig fra [redacted]ge i det angitte tidsrommet. Jeg som forsker vil være tilstede i et tilrettelagt prosjektrom på høgskolen sammen med barna og den ansvarlige fra barnehagen. En eller to faglige kollegaer fra en prosjektgruppe ved høgskolen vil også være tilstede i de ulike aktivitetene. Denne prosjektgruppen består av førsteamanuensis Kari Carlsen, stipendiat Ann-Hege Lorvik Waterhouse og høgskolelektor Marianne Christensen. Målet er å gjennomføre ulike aktiviteter der barna tar i bruk ulike materialer og digitale verktøy i undersøkende, utforskende og skapende handlinger. Gjennom deltagende

observasjon i barns møter med materialer og digitale verktøy vil jeg samle inn datamateriale som feltnotater, foto og video som skal danne grunnlag for mine analyser.

Barns samtykke
Forskning hvor barn er deltagere krever en sensitivitet hos meg som forsker når det gjelder barns eget samtykke. Juridisk er det foreldre som gir skriftlig samtykke til at barn kan delta, men som forsker vil jeg bruke tid på å etablere kontakt med barna og gjennom samtale gi informasjon om hvorfor jeg er sammen med dem. Barna skal hele veien gis mulighet til å si nei til å delta. De skal fortløpende gis mulighet til muntlig samtykke.

Personopplysninger
Alle personopplysninger vil bli behandlet konfidensielt. For å sikre deltagernes anonymitet vil ikke barnas navn registreres. I mine feltnotater vil jeg gi barna fiktive navn. Det er kun jeg, som leder av studien, prosjektgruppen og mine veiledere som vil ha tilgang til dette materialet. Video, bilder, samt feltnotater vil oppbevares i låsbart skap og på passord-beskyttet ekstern harddisk for å ivareta deltagernes anonymitet og personvern. Alle personidentifiserbare bilder samt video og feltnotater slettes etter planen i løpet av 2021 eller så fort avhandlingen er levert og endelig godkjent til graden ph.d. Barna vil ikke kunne gjenkjennes i publikasjoner. Som forsker er jeg underlagt taushetsplikt og alle data behandles konfidensielt. Prosjektet er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Frivillig deltakelse
Det er frivillig å delta i studien, og det vil ikke bli tatt video av et barn dersom foreldrene ikke har samtykket. Selv om du sier ja til å delta, på vegne av ditt barn, kan du når som helst og uten å oppgi en grunn trekke ditt samtykke til at ditt barn skal delta i studien. Dersom du trekker deg, vil alle data som vedrører barnet ditt bli anonymisert/slettet.
Barn som gir uttrykk for at de ikke ønsker å delta skal tas på alvor og ikke observeres, bli tatt bilder av eller filmes.

Samtykkeerklæring
Samtykkeerklæring underskrives og leveres til barnehagen innen fredag 16. februar 2018.

Ved eventuelle spørsmål kan du ta kontakt med meg på telefon 90961341 (mobil) eller 35026412 (arbeid). Jeg kan også kontaktes på mail: Lovise.soyland@usn.no
Min veileder Biljana Fredriksen kan også kontaktes på mail: Biljana.C.Fredriksen@usn.no

Vennlig hilsen
Lovise Søyland
Doktorgradsstipendiat ved Høgskolen i Sørøst-Norge.

Lovise Søyland
Høgskolen i Sørøst-Norge
Postboks 235
3603 Kongsberg

Kongsberg 08.02.2018

Til foreldre og foresatte til [redacted]

SAMTYKKEERKLÆRING FRA FORELDRE OG FORESATTE VED INNSAMLING AV MATERIALE I FORM AV OBSERVASJONER, FELTNOTATER, VIDEO OG FOTO I FORBINDELSE MED PROSJEKTET: *Sense-making i interaksjon mellom fysisk og digital materialitet. En studie av utforskende og skapende handlinger.*

Ansvarlig for prosjektet
Doktorgradsstipendiat Lovise Søyland, Institutt for estetiske fag ved Høgskolen i Sørøst-Norge

Jeg har mottatt skriftlig informasjon og er villig til at mitt barn deltar i studien.

.....	……..	……..
dato	Signatur	Signatur

Biljana Culibrk Fredriksen

3603 KONGSBERG

Vår dato: 02.03.2018 Vår ref: 59073 / 3 / AGL Deres dato: Deres ref:

Vurdering fra NSD Personvernombudet for forskning § 31

Personvernombudet for forskning viser til meldeskjema mottatt 08.02.2018 for prosjektet:

59073	*Sense-making i interaksjon mellom fysisk og digital materialitet. En studie av utforskende og skapende handlinger*
Behandlingsansvarlig	*Høgskolen i Sørøst-Norge, ved institusjonens øverste leder*
Daglig ansvarlig	*Biljana Culibrk Fredriksen*
Student	*Lovise Søyland*

Vurdering

Etter gjennomgang av opplysningene i meldeskjemaet og øvrig dokumentasjon finner vi at prosjektet er meldepliktig og at personopplysningene som blir samlet inn i dette prosjektet er regulert av personopplysningsloven § 31. På den neste siden er vår vurdering av prosjektopplegget slik det er meldt til oss. Du kan nå gå i gang med å behandle personopplysninger.

Vilkår for vår anbefaling

Vår anbefaling forutsetter at du gjennomfører prosjektet i tråd med:

- opplysningene gitt i meldeskjemaet og øvrig dokumentasjon
- vår prosjektvurdering, se side 2
- eventuell korrespondanse med oss

Vi forutsetter at du ikke innhenter sensitive personopplysninger.

Meld fra hvis du gjør vesentlige endringer i prosjektet

Dersom prosjektet endrer seg, kan det være nødvendig å sende inn endringsmelding. På våre nettsider finner du svar på hvilke endringer du må melde, samt endringsskjema.

Opplysninger om prosjektet blir lagt ut på våre nettsider og i Meldingsarkivet

Vi har lagt ut opplysninger om prosjektet på nettsidene våre. Alle våre institusjoner har også tilgang til egne prosjekter i Meldingsarkivet.

Vi tar kontakt om status for behandling av personopplysninger ved prosjektslutt

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Ved prosjektslutt 01.04.2021 vil vi ta kontakt for å avklare status for behandlingen av personopplysninger.

Se våre nettsider eller ta kontakt dersom du har spørsmål. Vi ønsker lykke til med prosjektet!

Dag Kiberg

Audun Løvlie

Kontaktperson: Audun Løvlie tlf: 55 58 23 07 / audun.lovlie@nsd.no

Vedlegg: Prosjektvurdering
Kopi: Lovise Søyland, lovise.soyland@usn.no

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 59073

Du har opplyst i meldeskjema at utvalget vil motta skriftlig og muntlig informasjon om prosjektet, og samtykke skriftlig til å delta. Vår vurdering er at informasjonsskrivet til utvalget er godt utformet.

Selv om barnets foresatte samtykker til barnets deltakelse i prosjektet, må også barnet gi sin aksept til å delta. Vi anbefaler at barnet mottar tilpasset informasjon om hva deltakelse i prosjektet innebærer. Du må sørge for at barnet forstår at deltakelse er frivillig, og at det kan trekke seg om det ønsker det.

Personvernombudet forutsetter at du/dere behandler alle data i tråd med Høgskolen i Sørøst-Norge sine retningslinjer for datahåndtering og informasjonssikkerhet. Vi legger til grunn at bruk av mobil lagringsenhet er i samsvar med institusjonens retningslinjer.

Prosjektslutt er oppgitt til 01.04.2021. Det fremgår av meldeskjema/informasjonsskriv at du vil anonymisere datamaterialet ved prosjektslutt. Anonymisering innebærer vanligvis å:
- slette direkte identifiserbare opplysninger som navn, fødselsnummer, koblingsnøkkel
- slette eller omskrive/gruppere indirekte identifiserbare opplysninger som bosted/arbeidssted, alder, kjønn
- slette eller sladde bilde- og videoopptak

For en utdypende beskrivelse av anonymisering av personopplysninger, se Datatilsynets veileder:
https://www.datatilsynet.no/globalassets/global/regelverk-skjema/veiledere/anonymisering-veileder-041115.pdf