Department of Art

Art education in the post-digital era

Experiential construction of knowledge through creative coding

Tomi Dufva

Aalto University

DOCTORAL DISSERTATIONS

Aalto University publication series
DOCTORAL DISSERTATIONS 72/2018

Art education in the post-digital era

Experiential construction of knowledge through creative coding

Tomi Dufva

Aalto University
School of Arts, Design and Architecture
Department of Art

Main dissertation advisor
Professor Helena Sederholm, Aalto University, the School of Arts, Design and Architecture

Co-dissertation advisor
Docent Tere Vadén, University of Tampere

Preliminary examiners
Professor Sirkku Kotilainen, University of Tampere
Assistant Professor Aaron Knochel, Pennsylvania State University, School of Visual Arts

Opponent
Assistant Professor Aaron Knochel, Pennsylvania State University, School of Visual Arts

Aalto University publication series
DOCTORAL DISSERTATIONS 72/2018

ISBN 978-952-60-7947-9 (printed)
ISBN 978-952-60-7948-6 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934 (printed)
ISSN 1799-4942 (pdf)
http://urn.fi/URN:ISBN:978-952-60-7948-6

Graphic design: Tomi Dufva
Images: Tomi Dufva

Unigrafia Oy
Helsinki 2018

Finland

441 697
Printed matter

Author
Tomi Dufva

Name of the doctoral dissertation
Art education in the post-digital era: Experiential construction of knowledge through creative coding

Publisher School of Arts, Design and Architecture

Unit Department of Art

Series Aalto University publication series DOCTORAL DISSERTATIONS 72/2018

Field of research Art education

Date of the defence 18 May 2018

Language English

☐ **Monograph** ☒ **Article dissertation** ☐ **Essay dissertation**

Abstract

This dissertation examines the questions and problematics of code and digitality brought forward by the post-digital era. In particular, it focuses on the role and the means art education has in awakening a critical understanding of the digital constructs in our society. Moreover, this dissertation proposes creative coding as an art educational method to gain a first-hand comprehension of digitality.

Increasing digitalisation is augmenting and altering our culture as well as society in general. Digital technologies mediate everyday life so much that not using them becomes a declaration of alternative values. The term post-digital delineates a world where the digital is complexly intertwined with the physical world. As such, digital technologies participate in the construction of society and everyday life. Post-digital presents multiple challenges in regards to everyday life, as well as to culture and society, which requires comprehension of these technologies and their underlying code. Without an understanding of how these digital systems work, we are unable to fully participate in the construction of contemporary life.

Creative coding, generally, refers to programming where expression is more important than function. This dissertation widens the concept of creative programming into activities that include programming as one of their components, such as physical computing and in some instances new media art. Furthermore, creative coding in this research is considered from the art educational perspective as an experiential activity that generates and requires creative and critical thinking.

My research methods are primarily based on phenomenology, ethnography, and theoretical research. The research material includes theoretical literature from the fields of art, art education, philosophy, and craft education, and from a varied field of studies on technology. The ethnographic material consists of my research at the Robotti Art and Craft School (Käsityökoulu Robotti). The phenomenological research strategy blankets the whole dissertation from me being the active participant in both teaching creative coding in various places as well as practising it in my artistic work.

The dissertation offers three key findings that have both theoretical and practical implications. The first is the observation that understanding digital technologies in general, and teaching programming in particular, needs to be understood from a broader perspective. The second is the notion of digi-grasping, which refers to the growing need to comprehend the complex and intertwined digital processes inherent in everyday life. The third is the implication that creative coding can be a beneficial tool in art education in acquiring knowledge and critical understanding of the digital systems.

Keywords Art education, code literacy, craft education, philosophy, digital humanities, creative coding

ISBN (printed) 978-952-60-7947-9 **ISBN (pdf)** 978-952-60-7948-6

ISSN-L 1799-4934 **ISSN (printed)** 1799-4934 **ISSN (pdf)** 1799-4942

Location of publisher Helsinki **Location of printing** Helsinki **Year** 2018

Pages 146 **urn** http://urn.fi/URN:ISBN:978-952-60-7948-6

Aalto-yliopisto

Tiivistelmä

Aalto-yliopisto, PL 11000, 00076 Aalto www.aalto.fi

Tekijä
Tomi Dufva

Väitöskirjan nimi
Taidekasvatus postdigitaalisella aikakaudella: kokemuksellinen ymmärtäminen luovan ohjelmoinnin avulla

Julkaisija Taiteiden ja suunnittelun korkeakoulu

Yksikkö Taiteen Laitos

Sarja Aalto University publication series DOCTORAL DISSERTATIONS 72/2018

Tutkimusala Taidekasvatus

Väitöspäivä 18.05.2018

Kieli Englanti

☐ **Monografia** ☒ **Artikkeliväitöskirja** ☐ **Esseeväitöskirja**

Tiivistelmä

Tämän väitöskirjan keskeinen teema on postdigitaalisuuden myötä nousseet kysymykset digitaalisuudesta ja koodista. Erityisessä keskiössä ovat taidekasvatuksen rooli ja mahdollisuudet herättää kriittistä ymmärrystä digitaalisuuden asemasta ja rakenteista nyky-yhteiskunnassa. Tämä tutkimus esittää luovaa ohjelmointia taidekasvatuksellisena menetelmänä ymmärtää digitaalisuutta sekä saavuttaa siitä omakohtaista tietoa.

Digitalisaatio muokkaa ja vaikuttaa sekä kulttuuriin, että laajemmin koko yhteiskuntaan. Digitaaliset teknologiat ovat läsnä arjessamme jopa niin paljon, että niistä kieltäytyminen voidaan nähdä kannanotoksi vaihtoehtoisten arvojen puolesta. Postdigitaalisuuden käsite viittaa tilanteeseen jossa digitaalinen teknologia on monitahoisesti punoutunut sekä yhteiskunnan rakenteisiin, että jokapäiväiseen elämään. Postdigitaalisuuden esiin tuomat haasteet vaativat ymmärrystä näistä teknologioista ja niiden taustalla vaikuttavasta koodista. Tämän ymmärryksen puuttuminen vaikeuttaa osallistumista postdigitaalisen elämän rakentamiseen.

Luovalla ohjelmoinnilla viitataan yleisesti ohjelmointiin, jossa ilmaisu on ohjelmoinnin funktiota tärkeämmässä asemassa. Tämä tutkimus laajentaa luovan ohjelmoinnin käsitettä taiteellisiin toimintoihin, joissa ohjelmointi toimii osana taiteen tekemistä, kuten esimerkiksi joissakin uuden median prosesseissa. Lisäksi luova ohjelmointi nähdään tässä tutkimuksessa taidekasvatuksellisesta näkökulmasta kokemuksellisena prosessina, joka sekä tuottaa että vaatii luovaa ja kriittistä ajattelua.

Väitöskirjan ensisijaisina tutkimusmenetelminä ovat fenomenologinen, etnografinen sekä teoreettinen tutkimus. Tutkimuksen poikkitieteellisen luonteen vuoksi tutkimusmateriaali koostuu niin taiteen, taidekasvatuksen, filosofian, käsityökasvatuksen kuin teknologian kirjallisuudesta. Väitöskirjan etnografinen osa koostuu pääosin Käsityökoulu Robotissa tehdystä tutkimuksesta. Fenomenologinen menetelmä toimii väitöskirjan kaikenkattavana menetelmänä: se luo tutkimuksellisen viitekehyksen omaan luovan ohjelmoinnin opettamiseeni kuin myös sen käyttöön taiteessani.

Väitöskirjani tuo esiin kolme tutkimustulosta, joilla on sekä teoreettisia että käytännöllisiä seuraamuksia. Ensimmäisenä on havainto siitä, että digitaalisen teknologian ymmärtäminen yleisesti, ja ohjelmoinnin opettaminen erityisesti, tulee ymmärtää nykyistä laajemmasta perspektiivistä käsin. Toinen tulos on huomio tarpeesta käsittää digitaalisuutta kokemuksellisesti ja kehollisesti. Käytän käsitettä *digi-grasping*, joka viittaa monitahoisten ja punoutuneiden digitaalisten prosessien laajempaan ymmärtämiseen. Kolmanneksi ehdotan väitöskirjassani, että luova ohjelmointi voi toimia hyödyllisenä menetelmänä taidekasvatuksessa ja auttaa digitaalisuuden kriittisessä ymmärtämisessä.

Avainsanat taidekasvatus, käsityökasvatus, ohjelmoinnin lukutaito, luova ohjelmointi, filosofia, digitaalisuus

ISBN (painettu) 978-952-60-7947-9 **ISBN (pdf)** 978-952-60-7948-6

ISSN-L 1799-4934 **ISSN (painettu)** 1799-4934 **ISSN (pdf)** 1799-4942

Julkaisupaikka Helsinki **Painopaikka** Helsinki **Vuosi** 2018

Sivumäärä 146 **urn** http://urn.fi/URN:ISBN:978-952-60-7948-6

Författare
Tomi Dufva

Doktoravhandlingens titel
Konstfostran i en postdigital era: erfarenhetsbaserad förståelse genom kreativ programmering

Utgivare Högskola för konst, design och arkitektur

Enhet Institutionen för konst

Seriens namn Aalto University publication series DOCTORAL DISSERTATIONS 72/2018

Forskningsområde Konstfostran

Språk Engelska

☐ **Monografi** ☒ **Artikelavhandling** ☐ **Essäavhandling**

Sammandrag
Den här avhandlingens centrala tema är de frågor om kod och digitalitet som den postdigitala eran har fört med sig. Speciellt centralt i forskningen är den position som konstfostran har och dess möjligheter att väcka ett kritiskt tänkande kring vilken roll och konstruktion digitaliseringen bär i vårt samhälle. Avhandlingen för fram kreativ programmering som ett medel för att inom konstfostran behandla digitalitet och skapa självupplevd förståelse av det digitala.

Digitaliseringen förändrar och påverkar vårt samhälle och vår kultur. Digitala teknologier är så närvarande i vår vardag att det ses som ett ställningstagande, som anger alternativa värden, om en människa vägrar att använda sig av digital teknologi. Begreppet postdigitalitet syftar till en situation där den digitala teknologin är sammanflätad med vardagen och samhällskonstruktionen. De utmaningar som postdigitalitet för med sig kräver förståelse av teknologi och den kod som finns bakom den. En bristande förståelse gör det svårare att medverka och till fullo bygga ett postdigitalt liv.

Med kreativ programmering avser man generellt programmering där uttrycket är i viktigare position än programmets funktionalitet. Den här avhandlingen breddar begreppet kreativ programmering till att omfatta en konstnärlig verksamhet där programmering är en del av skapandet av konst, till exempel i nya medias processer. Dessutom granskas kreativ programmering i den här avhandlingen ur konstfostrans perspektiv som en experimentell process, som både skapar och kräver kreativt och kritiskt tänkande.

Avhandlingens primära forksningsmetoder är fenomenologisk, etnografisk och teoretisk forskning. Eftersom avhandlingen är tvärvetenskaplig till sin natur, består forskningsmaterialet av litteratur från konst-, filosofi- och teknikfältet, liksom från ämnet hantverksfostran. Avhandlingens etnografiska del består huvudsakligen av forskning gjord i Käsityökoulu Robotti (Hantverksskolan Robotti). Den fenomenologiska metoden utgör basen för avhandlingen: den skapar den referensram jag använder mig av såväl i min undervisning som i min konst.

Avhandlingen påvisar tre centrala resultat som påverkar både teori och praktik. Först är insikten om att digitala teknologier i allmänhet och undervisningen i programmeringen specifikt bör sättas i ett bredare perspektiv. För det andra för avhandlingen fram digi-grasping, vilket innebär det ökade behovet att förstå de komplexa och sammanflätade digitala processer som är en del av vårt dagliga liv. För det tredje för avhandlingen fram att kreativ programmering kan vara ett förtjänstfullt medel för att skapa kunskap och kritisk förståelse av digitala system inom konstfostran.

Nyckelord Konstfostran, kodläskunnighet, hantverksfostran, filosofi, digital humaniora, kreativ programmering

ISBN (tryckt) 978-952-60-7947-9 **ISBN (pdf)** 978-952-60-7948-6

ISSN-L 1799-4934 **ISSN (tryckt)** 1799-4934 **ISSN (pdf)** 1799-4942

Utgivingsort Helsinki **Tryckort** Helsinki **År** 2018

Sidantal 146 **urn** http://urn.fi/URN:ISBN:978-952-60-7948-6

Acknowledgements

This research started with an earnest curiosity about understanding digital technology. I am grateful to all the people who have helped and guided me along the way, as well as to all the people who have contributed to my research. Without you, this research would not have gotten very far. First, I want to thank my professor Tere Vadén for his profound insights as well as his continuous support during this research. I want to thank equally my supervising professor Helena Sederholm for her countless advice and support and always finding the time to meet and help along the way.

During my research I have been privileged to take part in the FADS (Finnish Art Educator Doctoral Studies) network. FADS provided me with a network of fabulous Ph.D. students, postdocs, and professors. The yearly meetings and most of all the friends encountered, and informal discussions have very much helped me in the enduring wilderness of writing this doctoral dissertation.

I also want to thank professor Eeva Anttila from the University of Arts, first on the inspiring course of Freirean critical pedagogy and later for bringing me into the arts@school-research group, part of the Artsequal research initiative. The extended views from dance and theatre research have greatly expanded my notions of digitality. During my doctoral studies, I had the privilege to take a short research journey to the States, to discuss creative coding with distinguished professors. Not only did I have a fruitful discussion, but I was met with warmth and kindness. Thank you, professors Robert Sweeny, Marissa Sweeny, and Ryan Patton.

Then I want to thank the Aalto University, the School of Arts, Design, and Architecture for not only offering me a doctoral student position to finish my dissertation but for all the support and friendly faces at Aalto. In particular, I want to thank the head of our art department, professor Kevin Tavin, for having time for discussions as well as helping actualise the research trip to the States. Being able to focus on writing entirely is invaluable, and for that I am thankful. In the same vein, I want to thank the Jenny and Antti Wihuri Foundation for the grants in 2015–2017.

In 2016 at an international NordFo conference in Rauma, I had the pleasure of meeting Seija Kojonkoski-Rännäli and discussing the relationship between making by hand and digitality. This and our later correspondence have been more than helpful in forming my view on embodied digitality.

I am also thankful to everyone at Käsityökoulu Robotti for generously giving their time to fill in the questionnaires and answer interviews and most of all

for creating Käsityökoulu Robotti as a vivid school that has expanded into three cities and achieving more than I could have ever imagined.

I have had the enjoyment of collaborating with my brother, doctor Mikko Dufva, on two articles, as well as having many informal discussions on these topics throughout the research. Many of the concepts presented in this dissertation have been formed after inspiring talks with Mikko in our cottage sauna.

I also am forever grateful to my parents, not only for having a cottage sauna but for helping and supporting me in many ways during not only my doctoral studies but life in general. Similarly, I want to thank my sister and my family in general for their conversations and support.

Last, but not in any way the least, I want to thank my fiancée, Johanna: Thank you for your unwavering trust, your loving encouragement and the endless patience you have demonstrated in listening to, and discussing, my troubles along the way.

Turku, 19 March 2018
Tomi Dufva

Contents

List of Publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals

1. Dufva, T. & Dufva, M. (2016). Metaphors of code: Structuring and broadening the discussion on teaching kids to code. Thinking Skills and Creativity, 22, 97–110. DOI: 10.1016/j.tsc.2016.09.004

2. Dufva, T. (2017). Maker Movement: Creating knowledge through basic intention. Techne Series – Research in Sloyd Education and Craft Science, 24 (2), 129-141..

3. Dufva, T. & Dufva, M. (2017). Grasping the future of digital society'. [Article under review for Futures, The Journal of Policy, Planning and Futures Studies].

4. Dufva, T. (2018) Creative Coding at the arts and crafts school Robotti (Käsityökoulu Robotti) In Proceedings of the 3rd Digital Humanities in the Nordic Countries Conference. (DHN 2018) Helsinki, Finland. [Accepted manuscript]

Author's Contribution

In co-written publications 1 & 3 I was the main author and my contribution was in the writing of theoretical contexts as well as the discussions and conclusions.

1. Introduction

"It's early in the twenty-first century, and that means that these words will mostly be read by nonpersons—automatons or numb mobs composed of people who are no longer acting as individuals. The words will be minced into atomized search-engine keywords within industrial cloud computer facilities located in remote, often secret locations around the world. They will be copied millions of times by algorithms designed to send an advertisement to some person somewhere who happens to resonate with some fragment of what I say. They will be scanned, rehashed, and misrepresented by crowds of quick and sloppy readers into wikis and automatically aggregated wireless text message streams.

Reactions will repeatedly degenerate into mindless chains of anonymous insults and inarticulate controversies. Algorithms will find correlations between those who read my words and their purchases, their romantic adventures, their debts, and soon, their genes. Ultimately these words will contribute to the fortunes of those few who have been able to position themselves as lords of the computing clouds.

The vast fanning out of the fates of these words will take place almost entirely in the lifeless world of pure information. Real human eyes will read these words in only a tiny minority of the cases."
(Jaron Lanier, You Are Not a Gadget, 2010)

1.1. The post-digital era

In a recent lesson with 8-11 year-old children, we were coding an interactive portrait. Instead of me telling the students exactly how to do it, I gave them an example, but encouraged experimenting: how the code changes the size of the ellipse that represents the outline of the head or how editing the two other lines of code changes the size of the eyes. The result was a wide variety of different faces with unique expressions. This was our first coding session with the children and the first time most of the students had tried to code. Instead of rigidly telling them about the structures of code, or the logic, or the mathematic sides of code, we focused on the expressivity of the code. This expressivity is what underlines creative coding, emphasising expression above functionality. And through the creativity, the children adopted code as their drawing material, all creating something very personal from the few lines of code we wrote. This adoption of code can also be seen from one incident during the lesson: when explaining a variable to the children, I told them that they could name it anything they liked, that the computer doesn't mind; it's more for our own reference so that we know what is happening. Instead of everyone creating variables I wrote in my example, such as head, eyes, mouth, I saw variables named after their name, nickname, or another funny name. These variables were implemented flawlessly throughout the code, and besides communicating the meaning of the variable for the children, it seemed to create a more personal connection between the code and the children coding it. (Author's working notebook 10.9.2017.)

The aim of this dissertation is to discuss various themes within the post-digital era, such as the social, cultural, and philosophical aspects of code, through art educational methods and more precisely through creative coding. Contemporary life is profoundly intertwined with digital technologies. Digital devices mediate life at work and home. Culture and society are augmented and altered

through digital technologies. Advances in artificial intelligence and robotisation are changing the future of work, having large-scale effects on the economy and society (Ailisto, Collin, Juhanko, Mäntylä, & Ruutu, 2016; Makridakis, 2017; Morozov, 2014a). Blockchains offer new forms of value exchange, challenging, for instance, the banking industry, whereas wearable electronics, virtual and augmented realities are supplementing physical reality (Hayles, 2008; Uricchio, 2011). Security and privacy are questioned every day by companies, hackers as well as institutions, so much so that, for instance, privacy and identity (online) have become valuable and desired assets (Assange, Appelbaum, Müller-Maguhn, & Zimmermann, 2012; de Zwart, 2014; Howe, 2015; Morozov, 2014a; 2017). In sum, the ubiquity of digital technologies has an effect on every part of contemporary society.

The software/code component in digital technology introduces a layer of abstraction that brings forth new challenges to society (Cox, 2013; Fuller et al., 2008). The operation models of digital technology are not immutable laws of nature, but malleable frameworks whose structure is dependent on human decisions (Lessig, 2009). The underlying code in digital software and hardware is not value-free; rather, it widely reflects both the conscious and subliminal values of the programmer, the software company, or society's understanding of good code (Cox, 2013; Lessig, 2009; Rushkoff, 2010). Thus, understanding of the formation process of the surrounding digital structures becomes a question of inequality: without comprehension of the surrounding digital structures, it becomes hard or impossible to critique or change them (P. Freire, Freire, & de Oliveira, 2016; Giroux, 2011; Rushkoff, 2012).

Interestingly, as the world becomes further mediated by computer code, the code itself seems to disappear from plain sight, becoming embedded, hidden in increasingly sophisticated products (Berry, 2016; Jungner, 2015; Kittler, Mucke, & Similon, 1987). Albeit digital technologies exist in the material domain as computers, data centres, mobile devices, and as increasing amounts of e-waste and natural resource consumption (Gabrys, 2013), it is still the code that entangles the devices together. Code mediates our relationship with the world (Berry, 2016; Lessig, 2009; Petzold, 1999), so much so that we could see the use of the code, software, as a social experiment (Weiner, 1993). The coiled and complex relationship between everyday life and digital technologies could be seen as a move from the 'digital' era of increasing digitalisation into the post-digital era of entwined data streams between human and non-human actors (Berry, 2014) (Hayles, 2001).

Digital technology has transformed distinct sectors of the economy, culture, and society into one universal data form that can be collected, linked, analysed, edited, updated, and hacked with increasing speed and proficiency. These data streams are entangled in human lives in a multitude of different, complex, and even contradictory ways. (Berry, 2016; 2014). Berry suggests that digital technologies should not be thought of as objects of hardware or software, but as trajectories, real-time streams that flow in loops from one computer to another and from there to a person, only to be fed back into the computer again (Berry, 2014). Furthermore, the introduction of code allows for a new way of delegating mental processes to digital systems, which instils a greater

degree of agency to the digital devices. Digital technology turns everyday life into quantifiable metrics, data, to be used by others, usually for profit. Individuals rarely use the raw data, but instead they consume it in processed form, often offered to them by companies (Berry, 2016). For instance, Google uses its vast collection of data gathered from credit card transfers, Google searches, Gmail, Google Maps, Google Play Store and YouTube to tell when its users go and buy products from brick and mortar stores even without the use of tracked credit cards (Dwoskin & Timberg, 2017). The purpose of Google's tracking of individuals is reportedly to prove to advertisers that ads placed in Google's ad network function, but simultaneously Google's ability to predict human behaviour with certainty proves the scale of information collected, as well as its possibilities. Furthermore, the collected data are not just technical data, but through, for instance, social media platforms, companies can gather qualitative data on feelings and experiences (Berry, 2016; Wajcman, 2014). As such, the collected data accord these companies deep insights into individuals' lives, which in turn enables them to influence society in new ways (Berry, 2016; Morozov, 2014a; New Left Review, 2015; Steiner, 2013). For instance, they can influence elections (Grassegger & Krogeris, 2017), predict next summer's hit songs (Steiner, 2013), or close individuals into a filter bubble that feeds them only news and stories they 'like' (Pariser, 2012). Furthermore, the collected data that are sorted through algorithms seem to inherit human biases that can make the code act in racist, chauvinistic ways (Devlin, 2017; Editorial, 2017). These problematic uses of code are of special interest because of the economic models used by many companies: instead of offering a product for a price, they offer services for free in exchange for personal data, which are then used to erect a platform. These platforms then leverage their central position and either sell the data further or use their central platform as a means to make money. These business models affect the ways in which code is created, and products built.

The effects of digital technologies have awakened broad research interest in the recent years. Digital humanities, as well as comparative media studies, have reflected their position and aim in the post-digital age (Berry, 2016; Hayles, 2012). New fields of research have been established, for instance critical making studies (Hertz, 2015; Ratto, 2011), software studies (Fuller et al., 2008), critical code studies (Marino, 2006), digital code literacy studies (Hayles, 2010), platform studies (Bogost, 2010; Montfort et al., 2014), and societal and political studies interested in code and its cultures (Berry, 2008; Coleman, 2013; Turkle, 2005; 2011). These different fields point out the significance and extent of digital technologies in the contemporary world.

From the perspective of the arts, technology has always been crucial, whether in the form of material advances of artistic media, for instance, the invention of oil colours, or as a more abstract invention such as the invention and utilisation of perspective (Shanken, 2001). Although the contemporary art could not be accused of neo-Luddism (interest in machines trails back to futurism) (Berry et al., 2012; Taylor, 2014), digital art or new media art, meaning the broad spectrum of different art practices that employ digital technologies in some way, maintains a complex role in the contemporary art world (Berry et

al., 2012; Bishop, 2012; Chayka, 2012, Manovich, 1996). I will discuss these problematics further in the Digital art chapter (2.4.1). However, one perspective is offered by Berry (Berry et al. 2012), who distinguishes two lines of thought which, borrowing Manovich (1996) could be labelled 'Turing-land' (alluding to Alan Turing, the pioneer of digital computing) and 'Duchamp-land'. According to Manovich, 'Duchamp-land' possesses the following characteristics:

> "1) Oriented towards the 'content.' [...]
>
> 2) 'Complicated.' [...]
>
> 3) Ironic, self-referential, and often literally destructive attitude towards its material, i.e., its technology, be it canvas, glass, motors, electronics, etc. [...] "

whereas Turing-land emphasises quite contrary traits:

> "1) Orientation towards new, state-of-the-art computer technology, rather than 'content.' [...]
>
> 2) 'Simple' and usually lacking irony. See below.
>
> 3) Most important, objects in Turing-land take technology which they use always seriously." (Manovich, 1996)

Manovich's distinction between the two different lands (inspired by Disneyland) shows the contrast between the digital art sphere and the more mainstream contemporary art sphere. His critique is twofold: first, 'Turing-land' lacks criticism towards the new technologies; and on the other side, 'Duchamp-land' might be too focused on 'art' and not on the new possibilities brought by digital technology (Manovich, 1996). Although Manovich made his comment in 1996, such a division is still recognisable. As an example, Kiasma, the Finnish national gallery, recently held an exhibition focusing on post-Internet, post-digital art, bringing forth the relationships between digital technologies, everyday life, and contemporary art into mainstream discussion (Nykytaiteen museo Helsinki, 2017). The exhibition was critiqued as oversimplifying, messy and inconsistent (EDIT, 2017; net, 2017). In some respects, the exhibition at Kiasma could be seen to originate from the perspective of 'Duchamp-land', where the art world still shuns the technicality of digital technology, or the everydayness of digitality (Berry et al., 2012; Cox, 2013; Manovich, 1996). When life is increasingly intertwined with digital technology, such a division is unfortunate: art could present fresh perspectives and a needed critique as well as embracing the new language and medium of the digital (Cox, 2013).

One proposed way to overcome the gap between contemporary art and digital art is through a concept called New Aesthetics (Berry et al., 2012; Berry & Dieter, 2015). New aesthetics, originally a design concept, originates from

Bridle (2011), but has been taken forward by art theorists and artists (Berry et al., 2012; Berry & Dieter, 2015; Bridle, 2011), and "naturally disregards established divides of creative industries, art practice and theory" (Berry et al., 2012, p. 5). The new aesthetics has been described as an "attitude, a feeling, a sensibility" that recognises the presence of digital technologies in the physical world and how contemporary visual languages are dependent not only on natural languages but the languages created by machines (Contreras-Koterbay, 2016, p. 9). As such, new aesthetics could be seen not (only) as a new theory of beauty but as a theoretical approach, and as art-making in the post-digital era: Digital art is no longer about dystopias, multiple screens, or dark robots, but art practice that is interwoven into the post-digital fabric of society and culture (Berry et al., 2012; Contreras-Koterbay, 2016).

Visual culture and digital literacy studies have tackled the growing use of digital technologies in art education (Keifer-Boyd, 1996; Sweeny, 2010; Taylor & Carpenter, 2015). However, these studies, as well as art educational practices, have stayed away from the direct study and use of code. In general, the main goals of post-modern art education align directly with creative coding as represented in this dissertation: critical and creative thinking, experiential learning, and the searching, and deconstructing of culture through various perspectives, as well as inspecting culture through different sub- and microcultural aspects (Efland, Freedman, & Stuhr, 1996; Erickson & Räsänen, 1999; The Finnish Association of Art Schools for Children and Young People, 2013).

Knochel and Patton remark that there appears to be a gap between studies focusing on the technical use of software and more theoretical approaches to digital media studies (Knochel & Patton, 2015). My research follows along the lines of Knochel and Patton, who suggest creative coding as a bridge between the critical theoretical studies and the practice-oriented studies. Creative coding in art education can be used as a method to critically assess the meaning of code in everyday life (Knochel & Patton, 2015). However, whereas Knochel and Patton liken the use of code in creative coding to the term computational thinking as a method for "developing students' critical awareness regarding the electronic devices and software they use daily" (Knochel & Patton, 2015, p. 27), I am referring more to the practices of code literacy as well as using creative coding as an art method itself (Jagodzinski et al., 2017). The context of code literacy connects to the art educational objective of critical thinking, whereas the code as art method links to post-modern theories of art education (Efland et al., 1996).

Code literacy relates to the ability to read and write code (Rushkoff, 2012), but can also be understood more largely as the capacity to understand the context of code and its connections to culture, society, and everyday life. Code literacy can thus be likened more to critical literacy than literacy. As such, code literacy approaches critical theory (Berry, 2014), critical code studies (Marino, 2006), and digital humanities (Berry 2016, Hayles, 2012). Media education can also be linked to code literacy through its interest in literacies, more specifically through its interest in understanding literacies from sociocultural perspectives (Knobel & Lankshear, 2007). The common thread here is the critical analysis of digital technology and its underlying code from social, cultural,

economic, political, and historical perspectives. Furthermore, code literacy can be comprehended as an empowering educational method, allowing students to gain a critical understanding of the dominating forces in society. Thus, code literacy could be likened to critical pedagogy's way of approaching digital technologies (Freire et al., 2016; Giroux, 2011).

Creative coding is generally described as programming where expression is more important than function (PBS, 2013). Creative coding transforms coding into an artistic tool or medium, which can be as fluid as drawing (The Art Club, 2017), or likened to any other process in the art studio (Knochel & Patton, 2015). In the art educational context, creative coding can be seen as what Knochel and Patton (2015) call a 'boundary shifter', a way of "impacting learning by inviting complex relationships and offering models for challenging thought" (p. 32) through the bricolage of artistic and digital technology practices.

This dissertation aims to broaden the comprehension of creative coding as an art educational practice by opening and deepening the concept of creative coding and by situating it in the context of a larger educational framework that draws its understanding of digitality from various cultural and societal sources. Furthermore, the articles in this dissertation discuss the various aspects digitality poses in the post-digital world. Alongside Knochel and Patton's article (2015), creative coding, or using code in general, in art education has been given little focus. But, as Knochel and Patton, among others, state, the ubiquitousness of digital technology, as well as its complex and coiled status in contemporary life, creates a situation where digital technologies already exist in the life of students as well as an art practices and art understanding, making digital technologies an essential subject for art education (Berry, 2016; Berry & Dieter, 2015; Cox, 2013; Knochel & Patton, 2015). Creative coding thus works not only as an artistic medium or as a method to learn how to program, but as a process through which one can comprehend and critique the surrounding digitalised world more clearly.

1.2. Objectives and scope

The change to a post-digital era is naturally reflected in the landscape of children and teenagers. Furthermore, digital technologies introduce new challenges for education: how does one explore digital technologies critically? How much should one understand of the technologies behind the digitality? How do digital technologies affect education or future work? How do digital technologies alter, transform, and create culture and sub-cultures? The objective of this dissertation is to offer one path into digitality through art education.

The art educational context offers an alternative perspective to digital technology in contrast to the hard science approach usually appended to teaching programming or technology in general (Dyson et al., 2009; König et al., 1985). The context of art education does not, however, only relate to the design choices of creating software or hardware or to the aesthetic elements apparent in the products. Rather, art education offers a unique method of critical inspection of digital technology and its effects from various perspectives. One of

the strengths of art education is its possibility to merge individual experiences and abstract concepts (Kolb, 2014; Räsänen, 1999). Furthermore, using digital technologies as a material in art-making may produce notable works of art that offer new perspectives on the contemporary post-digital world (Cox, 2013).

The four articles in this dissertation aim to broaden the perspective of living with digital technologies. By offering methods of comprehending as well as taking control of digital technologies, the purpose of this dissertation is educational and empowering. The main research question is: how does creative coding as a practice increase our knowledge and comprehension of the digital structures of everyday life?

The articles in this dissertation create a path into the post-digital landscape. The pathway starts with the first article's focus on teaching programming, from which it progresses to contemplating the relationship between the physical, or 'real', world and the digital world, and ends in the fourth article's focus on creative coding as a practice at Käsityökoulu Robotti (Robotti Art & Craft School). The articles give an expanded view of the digital landscape, especially from the perspective of the arts and critical thinking.

The first article "Metaphors of code—Structuring and broadening the discussion on teaching children to code" takes a look at the discussions around teaching programming in the basic curriculum. The article starts by disseminating programming with the help of metaphors and paradigms into distinct perspectives to give a comprehensive understanding of programming in the post-digital era. The article broadens the view of programming from its dominant functional paradigm as an important logical skill into programming as an intricate web of societal, economic, and cultural threads.

What is being in the digital world or the in-between of physical and digital worlds, and what does digital making by hand mean are the prominent questions of the two following articles. The first of these, the second article in this dissertation, "Maker Movement - Creating knowledge through basic intention," focuses on the making by hand aspect of creative coding. Moreover, following Finnish craft professor Kojonkoski-Rännäli, the article takes a look at the maker movement and its relationship to the theories of making by hand. The third article broadens the handicraft aspect to embodiment, asking how should and could one embody a world that is simultaneously physical and digital.

The final article forms an overarching bridge connecting the set of articles by focusing on the practice of creative coding in art education. The main focus is on the ethnographic study of Käsityökoulu Robotti (Robotti Art & Craft School), a school that focuses on teaching art and technology. Whereas the first three articles construct a theoretical background for creative coding, the final article utilises the outcomes of the previous articles and expands further on the practical use of creative coding as an educational method in art education. The article offers insight into the benefits of combining art in teaching digital technologies. The questions and outcomes are displayed in Figure 1 and are further discussed in the third chapter.

My research in creative coding is fundamentally cross-disciplinary and therefore participates in various distinct discussions. In this dissertation, I have chosen to focus broadly on three discussions: first, the debate on code in the context of education in general. Second, my research on embodiment and digitality connects my research into the post-human discussion and more broadly into the phenomenological discussion of craft and art. Lastly, my focus on creative coding joins my work on the discussion of art and more specifically digital and software cultures. In the following sections, I will briefly describe how my dissertation takes part in these discussions, and my contributions to each discussion.

The debate on teaching programming has been active in recent years, maybe resulting from several countries taking programming into their basic curricula in one way or another (Dredge, 2014; Mykkänen & Liukas, 2014; White House, 2014; Toikkanen, 2015) and partly of the ongoing trend of digitalisation, followed by robotisation, and artificial intelligence. My research contributes by broadening the discussion from the functional aspect of teaching programming, i.e., what tools, and languages to use, to more cultural and philosophical aspects. My research aligns somewhat with the critical code discussions of, for example, Williamson, Berry, Cox and even Hayles (Berry, 2016; 2014; Cox, 2013; Hayles, 2008; Williamson, 2015) in understanding code and digitality as a large and complex phenomenon that embodies everyday life. Moreover, the research joins this discussion from the more hands-on approach of creative coding as an active experience. In addition, the research critiques strictly functional perspectives of coding that see teaching programming from the simplistic view of teaching programming languages or logics without seeing the broader perspectives inherent in programming in an age of ubiquitous computing and digitality.

Second, the dissertation deals with the question of embodiment in digitality: how one sees oneself in the digitalised world. The dissertation relates to post-humanistic discussions, where it connects more with the embodied perspectives offered by Haraway (2013) and Hayles (2008; 2010), who emphasise the importance of an embodied understanding of being instead of the clear divide between mind and body present in, for example, Kurzweil's (2005) and Moravec's (1988) theories. Furthermore, the embodied digitality discussion connects this research with phenomenological theories presented in the digital context, for instance, by Dreyfus (2008), and inherent in art theories (Erickson & Räsänen, 1999) as well as craft theories (Kojonkoski-Rännäli, 2014). Here, my research contributes to the discussion of everyday digitality: how one experiences and embodies digitality in everyday situations and how craft and art help in this process. As such, the research does not explicitly discuss virtual reality or the use of digital devices, but, rather, the relationship between the digital and physical.

Third, the discussion of creative coding in art education contributes by further structuring the conversation around creative coding by expanding the understanding from computational thinking to a more critical thinking and by constructing code as a material for art-making. This is an aspect that is not much studied in art education, as referred to by Knochel & Patton (2015). As

Figure 1. Research questions and main outcomes of each article

such, my research contemplates e creative coding in art spheres as well as in software cultures.

1.3. Methodology

Because of the interdisciplinary nature of this research, crossing borders from technology and societal studies to art and art research, this dissertation uses multiple research methods. As a whole, the research could be considered as a qualitative study, where various strands of research strategies collide, from the

aforementioned art experiential method along with ethnographical, theoretical, phenomenological, art-based, and artistic research studies (Barone & Eisner, 2011; Denzin & Lincoln, 2008; Hannula, Suoranta, Vadén, Griffiths, & Kölhi, 2005; Patton, 2002). These research strategies coincide with each other in a process that can be likened to design research, where theoretical and practical processes follow each other in an iterative loop (Koskinen, 2011; Michel, Joost, & Mareis, 2014). Furthermore, design research "plays an important role in illuminating and tackling many complex problems facing the world today. It encourages and enables social change and challenges assumptions and beliefs about how we live, work, and consume. It raises questions that prompt us to consider other possibilities" (Koskinen, 2011, Kindle Locations 139-141). As such, design research is close to art-based research on broadening the understanding of complex problems (Barone & Eisner, 2011). However, this research is not concerned with digital technology from the viewpoint of its users, or usability, but rather emphasises the role of the individual as well as critical understanding and empowerment towards the digital. Furthermore, this research deploys art-making, especially coding, as a means to expand the comprehension of the phenomena of the digital. Thus, the dissertation, even though it does not include any art work per se, can be seen as an artistic research project (Hannula et al., 2005). The artistic research aspect also works in the margins of this dissertation: aside from my research, I work as a visual artist using creative coding consistently in my art work. Artistic work thus influences my thinking processes in the context of phenomenological research and accumulates my knowledge on the topics of code, electronics, and robotics. Through these different research strategies, the primary focus of this dissertation is the development of the method of creative coding and researching its usability in education.

During my doctoral studies, I have been part of the Artsequal initiative's Arts@school-group, with a focus on digitality and art education. Furthermore, I have been teaching creative coding for craft teachers and craft teacher students at the Universities of Turku, Tampere, and Helsinki and art education students at Aalto University, in the school of Arts, Design, and Architecture. These projects have shaped my understanding of creative coding as well as functioning as a platform for experimenting with different approaches to teaching creative coding, or programming in a more general context. In addition to these projects, the most prominent space for this research has been Käsityökoulu Robotti (Robotti Art & Craft School), of which I am co-founder and an active member. Käsityökoulu Robotti has impacted and altered the ways in which I think about creative programming and digital technologies in general. Käsityökoulu Robotti is discussed more closely in the fourth article, where I take an ethnographical approach to creative coding as a teaching method at the school. However, Käsityökoulu Robotti forms an important point of reference for the whole of the research.

The qualitative research strategies construct the general framework for this dissertation. The first three articles are largely theoretical research, based on earlier research on societal, cultural, educational, and technological studies of digital technologies, art, and craft education, philosophy, and sociology. As the

research subject in these three articles crosses and joins many different fields of research, the first three articles could be seen to provide new insights into digitality by attempting to bring these distinct fields together. The first article draws its context from theoretical research on pedagogy, digital technology, and societal studies. The article uses metaphors as a method to look at the questions of teaching programming. The second article employs a theoretical research strategy focusing on the philosophy of phenomenology by comparing craft research's view of making by hand to the view in the maker movement. The article takes a phenomenological look at making by hand in the digital era. The third article expands the phenomenological view of digitality with conceptual research that draws from the discussions of the philosophy of embodiment and the philosophy of the digital. The fourth paper focuses on creative coding as a research method at Käsityökoulu Robotti and is a longitudinal ethnographical research study on the teaching at Käsityökoulu Robotti.

In general, this dissertation aims to broaden the discussion around digital technologies, digitalisation, and the current state of digitality, which in this study is described as post-digitality. Moreover, it seeks to convey the utility as well as the distinct advantages of including art and art-based perspectives in the educational context of digital technologies. The articles in this dissertation describe the digital condition from various perspectives as well as displaying how creative coding could be utilised in education.

2. Theoretical foundation

> *"Science is knowledge which we understand so well that we can teach it to a computer; and if we don't fully understand something, it is an art to deal with it." (Knuth, 2007, p. 36)*

Because of the multi-disciplinary nature of this dissertation, its framework draws from multiple literatures. Art, art education, making by hand, and the philosophies of the digital play a significant role. This chapter is divided into four sections which together create the theoretical framework of this research. The first three sections present the three major perspectives relevant to the dissertation. The first section defines concepts related to art and art education. The next section discusses concepts linked to digital technologies and the third presents relevant theories concerning making by hand. The last section deals more closely with the intersection of art and digitality.

2.1. Art

Anecdote of the Jar
BY WALLACE STEVENS

I placed a jar in Tennessee,
And round it was, upon a hill.
It made the slovenly wilderness
Surround that hill.
The wilderness rose up to it,
And sprawled around, no longer wild.
The jar was round upon the ground
And tall and of a port in air.
It took dominion everywhere.
The jar was gray and bare.
It did not give of bird or bush,
Like nothing else in Tennessee.

Art operates as a starting point in this dissertation: art gives the needed tools to both critically assess and experience and create within the digital realm. In this dissertation, art acts as a frame, method, and background through which the phenomenon of digitality is comprehended. Art is understood both as an activity and an experience: action towards the digitalised world through experiencing, and experience of the digital world through creating with digital technology. This first section presents my theoretical framework in terms of art and art education, particularly from the context of digitality.

2.1.1. Art as exploration

The task of defining art leaves one with a feeling of wonderment. Earlier definitions of beauty, harmony, and proportion have vanished and mutated. Furthermore, modernism and post-modernism have dematerialised and conceptualised art and our concept of it in various ways (Dissanayake, 1992; Mitchell

& Hansen, 2010). However, in this dissertation art is comprehended from a broad perspective: art is understood as a governing mechanism, a vital element in human comprehension and knowledge-making, that "can only be ignored at our peril" (Read, 1970, p. 14). This understanding is close to Dissanayake's concept of making special (Dissanayake, 1992) and Noë's definition of art as an organisational activity (Noë, 2015). Common to all of these different theories is that they understand art as embodied, bodily, action that shapes one's knowledge and understanding of the surrounding world.

Dissanayake uses Wallace Stevens' poem "Anecdote of the Jar" as an example of 'making special' in her book *Core of Art* (1992). In brief, art has the ability to transform the mundane into something special, or worth further inspection. In the case of Stevens's poem, an everyday jar is lifted onto a pedestal. At the same time, the focused look at the mundane, in the case of Stevens's poem, the jar, can reveal something about being human, or of society, that might not otherwise reveal itself. Similarly, Alva Noë (2015) speaks of art as an organisational and reorganisational activity that furthers understanding of the surrounding world. In sum, art is a vital activity that forms and reforms our understanding of our lives and of the world.

Furthermore, seen from this context, art offers a path to exploration. As such, art in this dissertation is a research activity along the lines of arts-based research and artistic research. One of the benefits of arts-based research is its "broadening of conceptions of how we come to know" (Barone & Eisner, 2011, p. 23). The broadening acts as a heuristic method through which one's understanding of the complexities of the world can be deepened (Barone & Eisner, 2011). Following Dewey, art can be understood as a form of human experience, where creating art leads to learning (Dewey, 1998). In the context of the post-digital, the ubiquitousness and entangled nature of the digital technologies in our everyday life, art-based research offers invaluable tools for widening the perception of digitality.

Artistic experientiality also ties art-making to artistic research in the way it conveys and expands meaning (Hannula et al., 2005). Artistic research can be seen to accumulate knowledge in a way that broadens and deepens the understanding of the phenomena, or even affords alternative interpretations of the subject (Hannula et al., 2005). In this research, art is defined along these lines, as a significant activity (where the distinction between the 'artist' and the 'audience' is blurred) that can uncover things that might be difficult or impossible to do otherwise.

In particular, this dissertation discusses art in the context of digital technologies, and digitality as a cultural, societal, and political phenomenon. Art in some cases is seen to oppose the mechanical side of technology by emphasising more humanist values (Knochel & Patton, 2015; van Boeckel, 2013). However, the concept, as well as the role, of art often emerges in technological discussions (Knochel & Patton, 2015; Knuth, 2007; Taylor, 2014). Nevertheless, the conception of art in the context of technology is often vague. For instance, many projects that aim to introduce engineering to schools have an art component, but often the segment of art translates more into design selections than art per se (see for instance the initiatives in the US and Finland (Mykkän-

en & Liukas, 2014; "Steam Not Stem", 2010; “STEM to STEAM”, 2016). Furthermore, art in the context of digital technologies may refer more to pleasing aesthetics or visuals than to art as an activity of critical assessment and autonomy (Cox, 2013; Shanken, 2001; Taylor, 2014). However, in this dissertation the view of art as a sense-making and knowledge-building method is essential. Art is the explorational vehicle through which the post-digital world is examined. Furthermore, in creative coding, art, rather than the functionality of the code, gives the inspiration and reason for coding.

2.1.2. Aesthetics and creativity

The concepts of aesthetics and creativity are used in this dissertation in the context of digital technologies and art. However, both of these concepts, aesthetics and creativity, consist of multiple understandings and readings. Therefore this section provides clarification on how these concepts are used in this dissertation.

Aesthetics

Aesthetics comes up most prominently in this dissertation in Article 3 in the framework of the phenomenological understanding of making by hand, where aesthetic refers to a particular mode of being in the world (Heidegger, 2009; Husserl, 2013; Merleau-Ponty, 2012). We perceive the world primarily through our body and senses, and through our body we create our world as well as our knowledge of the world (Heidegger, 2009; Merleau-Ponty, 2012). Kojonkoski-Rännäli uses the concept of basic intention to refer to the preliminary connection one has with the world when one engages in doing a process by hand: making by hand not only creates an artefact but shapes the maker’s surrounding world, their knowledge of the world, and their connection to that world. Thus, making by hand develops and integrates makers ethically as well as aesthetically into the surrounding world (Kojonkoski-Rännäli, 1995; 2014). The use of the term 'aesthetic' in this research refers to that kind of phenomenological forming of the connection to the surrounding world. As such, the concept of aesthetics in this dissertation does not denote any particular set of aesthetic values, but rather highlights a bodily and sensory mode of forming a connection to the world.

Creativity

The concept of creativity is brought up several times in this dissertation, most prominently in the discussions of creative coding, where creativity could be seen to oppose the functionality of the programming and suggest an alternative way of using code, or digital technologies in general (Munster, 2006; PBS, 2013). Creativity in creative coding also refers to the use of code as a material or medium in art (Knochel & Patton, 2015; PBS, 2013).

Similarly, creativity is used in this dissertation in the context of art and technology, where creativity signifies one's freedom to choose the perspective, pro-

cess, or method of creation regarding digital technologies, as opposed to a more rigid, procedural process often common in technologies. For instance, in Article 4, in an interview with a teacher at Käsityökoulu Robotti creativity was used in the context of using tools and electrical components: in this regard, creativity denoted the freedom to use tools and components in a way that was functional, but not necessarily 'by the book'. In sum, the use of the term 'creativity' refers to the possibility of choosing one's viewpoint on digital technologies, as well as the adoption of this attitude in using digital technology. The use of creativity could thus be likened to Sternberg and Sternberg's definition of creativity as producing "something original and worthwhile" (2011, p. 479). Furthermore, creativity in this research does not denote the creation of novel products or new solutions, as proposed for instance by Mumford (2003).

2.1.3. Embodiment and art

In defining embodied knowledge, I refer to research that is based mostly on phenomenology. According to phenomenology, the way humans exist in this world is through bodies, thus people are restricted to a subjective view of our situated bodies (Husserl, 2013). The importance of embodiment in this dissertation emerges from the context of embodied digitality, which is discussed more broadly in Article 2 and specifically in Article 3, where I introduce the term 'digi-grasping' as a way of talking about embodied being in the in-between state of digital and physical. This section presents the definition of embodiment as understood in this research as well as its importance in the context of art.

Embodied knowledge

Embodiment has a double sense, as pointed out by both Merleau-Ponty and later Varela: "It encompasses both the body as a lived, experiential structure and the body as the context or milieu of cognitive mechanisms" (Merleau-Ponty, 2012; Rosch, Thompson, & Varela, 1992, p. XVI). This notion highlights a crucial point: the body is an active participant not only as a place for our senses but also as a place where knowledge is formed. Kojonkoski-Rännäli emphasises Heidegger's notion that, since humans are active bodily beings, existing in the world is realised through making, through doing by hand (Kojonkoski-Rännäli, 1995). However, it should be noted that even though making by hand and doing by hand are referred to throughout this dissertation, this does not necessarily require the use of the hands, but refers to any intentional physical activity that focuses on creating or shaping one's world.

Merleau-Ponty uses the term 'grasping' to point to an activity that is intentional but not necessarily conscious. It is possible to grasp something before knowing it; through the body, humans comprehend not only the spatiality of position but the spatiality of the situation (Merleau-Ponty, 2012). The relevance of grasping is in how it creates and shapes the knowledge of the experienced world through the body and embodied action. The body plays an im-

portant part in knowledge creation and produces knowledge that would be hard to gather otherwise (Dreyfus & Dreyfus, 2004; Merleau-Ponty, 2012).

The importance of embodied knowledge is that through several overlapping research strands such as phenomenology, cognitive science, and especially embodied cognitive theory and enactivist theory, it shows how the mind cannot be seen as separate from body or bodily experience (Lakoff, 2013), how the mind is built in interaction with the environment (Rosch et al., 1992), and how the mind can be seen to be situated in the whole body (Noë, 2003; 2004; 2015).

Embodiment in art

In general, art can be seen to relate to body and embodiment through various channels (Chaplin, 2005). For instance, Dissanayake presents three main approaches from the socio-biological standpoint: first as an aesthetic attraction that can be seen to influence evolutionary processes, second, as a 'biopetics' that presents art as a way to emphasise and preserve significant moments for the human species (birth, death, rites of passage, marriage), and third as developing cognitive and physical traits through art-making (Dissanayake, 1992). Furthermore, Dissanayake presents her theory of 'making special', discussed in Section 2.1, where art plays a substantial role in elevating particular moments or things in human life (Dissanayake, 1992).

This research discusses embodiment in art through the context of phenomenology. Art and phenomenology share similarities in their approach to perceiving the world (Merleau-Ponty, 2012), or 'being-in-the-world' in Heideggerian terms (Heidegger, 2009). Perception of the world is an embodied activity that is more than just biological functioning, but rather a set of complex culturally mediated embodied experiences one has in the world and of the world (Merleau-Ponty, 2012). Furthermore, Merleau-Ponty sees art as a creation of embodied knowledge. For instance, a paint brush can be considered as an "appendage of the body, a bodily synthesis" (Merleau-Ponty, 2012, p. 145) that works as an apparatus for the painter to see or perceive the world. This kind of embodied knowledge that happens through art can recapture pre-reflective experience and thus present the perceived world in a new light. The view Merleau-Ponty offers can be seen to bear a resemblance to Noë's (2015) view of art as organisational and reorganisational activity.

Merleau-Ponty's 'bodily synthesis' and views on embodiment, in general, can also be seen as a starting point for the post-human embodiment discussions of, for instance, Hayles (2010) and Haraway (2013), who have challenged the relationships of human beings and intelligent machines and furthermore the dichotomy of mind and body. In contemporary art, these theories can be seen, for instance, in the works of Stelarc or Orlan, who fuse technologies with their body, or to put it in another way, use their bodies as platforms (N. Czegledy & Czegledy, 2000; STELARC Hamburg City, 1999). Embodiment in digitality is discussed more in Section 2.2.7.

2.1.4. Art education in the post-digital era

One of the main themes in this dissertation is studying methods of managing the increasing digitalisation through art education, or how art education can help in the comprehension of the post-digital era. This research suggests, along the lines of Knochel & Patton (2015), that the way art education integrates critical thinking with physical activity has a substantial value in empowering students in the post-digital world. This section defines the framework of art education used in this dissertation.

The art educational view in this research is inspired by the experiential art interpretation (Erickson & Räsänen, 1999; Räsänen, 2000), itself influenced by Kolb's (2014) experiential learning model. The basis for this model is the process of using art in constructing and understanding self. Experiential art understanding combines art history, aesthetics, and critical thinking with experientially based processes of observation, conceptualisation, and production (Räsänen, 1999). In this framework, art education can be seen as a way of creating bridges between abstract thinking and experience (Parsons, 1987; Räsänen, 2000). Furthermore, this dissertation aligns with art education's role creating and developing creative and critical thinking, as well as exploring the tonalities and structures within cultures (Efland et al., 1996; Ettinger, 1988; The Finnish Association of Art Schools for Children and Young People, 2013).

In general, the main goals of post-modern art education align directly with the goals of creative coding, as represented in this dissertation: critical and creative thinking, experiential learning and searching and deconstructing culture through various perspectives, as well as inspecting culture through different sub- and microcultural aspects (Efland et al., 1996; Erickson & Räsänen, 1999; The Finnish Association of Art Schools for Children and Young People, 2013).

Technology transforms ways of understanding the surrounding world (Heidegger, 2013). This transformation can be seen as a substantial artificial force that impacts the reality humans live in (Ellul, 1990). From the context of digital technology, the rate of the transformation can be seen to be further accelerating, consequently creating a complex network where abstractions of digital technology merge into everything (actions, objects, other abstractions), i.e. digital technologies mediate increasing amounts of everyday life (Berry, 2014; Berry & Dieter, 2015). Thus, the interaction between the abstract and concrete, the ability to anchor abstract concepts in experience, becomes crucial when dealing with the digital world (Lessig, 2009; Rushkoff, 2010; 2013).

Integrating digital technology into art education has been proposed already in the 1980s (Ettinger, 1988). Furthermore, using art educational practices in understanding programming and digital technologies stems from Papert's constructionism and ideas of using computers in education (Knochel & Patton, 2015; Papert, 1993). However, even though art education has embraced digital media in the forms of hypertext, net.art and social media (Colman, 2015; Keifer-Boyd, 1996; Knochel, 2013; Taylor, 2000; Taylor & Carpenter, 2015), programming has not been widely integrated into art educational practices, but has stayed in the territories of mathematics (Knochel & Patton, 2015).

Knochel and Patton point out that because much of students' culture is mediated through programmed environments, art education should reflect that situation by introducing programming into art education (Knochel & Patton, 2015). Furthermore, programming in the context of art education can bring forward critical thinking on digital technologies: art education has the advantage of not following prescribed protocols or processes; instead, art can be a form of bricolage, open-ended and interdisciplinary practice in the digital medium (Knochel & Patton, 2015). In this dissertation, the concept of creative coding is used as an art educational, experiential art understanding method to combine the abstract and concrete in a way that is meaningful for the learner. The method of creative coding is discussed further in Section 2.4.2.

As the research deals with the relation between art education and digital technologies, it includes a connection to media education. For instance, in Finland, art education had integrated media education as part of its curriculum already in the 1950s (Kupiainen, Sintonen, & Suoranta, 2008). However, media education in art education offers only one perspective on media education. Buckingham (2000; 2003), for instance, sees media education as a continuation of the ethos of enlightenment. Kupiainen, Sintonen, and Suoranta (2008) conclude that media education can be seen from three major perspectives: first from the perspective of technology education, that emphasises the technical use of the media, second from the perspective of art education and a focus on expression through the media and last from the societal perspective of evaluating the media and its impact in society and culture. However, this research does not draw a separation between distinct perspectives in media education, but considers them as a whole, where the distinction comes from the choice of focus. This dissertation employs the concepts of art education because of its focus on the experientality of the phenomena that in turn offers both the side of theoretical, critical thinking as well as practicality in the form of technical use and expression. Therefore, identical or similar questions asked in the field of media education are purposely left outside of this dissertation and are instead discussed in the framework of art education and craft education as well as from the philosophical and societal frameworks defined in the theory section. However, it should be noted that this research dives into the critical understanding of digital media, and as such shares connections to critical technology education (Saariketo, 2017) and the societal and cultural aspects of media education (Kiilakoski, 2012; Kupiainen, 2005; Saariketo, 2015).

2.2. Philosophy of the digital

> *"Not only are we transformed by the way we use our tools; we are not aware of how we are being transformed, so we need all the more to try to make explicit what the Net is doing for us and what it is doing to us in the process." (Dreyfus, 2008, p. 137)*

The overarching theme in this dissertation is the ubiquitous nature of digital technologies and how they affect everyday life. This and the following sections define some of the core concepts and frameworks used in this research. Philosophy of the digital implies a deeper introspection into digital technologies,

creative coding being a central point of focus. Therefore, some of the discussions relevant to digital technologies, such as sustainability and materiality (Gabrys, 2013; Kohtala, 2016; Munster, 2006) are only briefly mentioned, even though in a wider context they would surely deserve larger emphasis. The discussion draws from several sources, such as the histories of digital technologies (Ceruzzi, 2012; Petzold, 1999), societal research on technology (Dyson et al., 2009; Howells, 2013; König et al., 1985), the digital humanities discussions (Berry, 2016; 2014; Hayles, 2012), media studies (Cubitt, 2007; Mitchell & Hansen, 2010; Rushkoff, 2010; 2013; 2016; Saariketo, 2015), embodiment and post-human discussions (Dahlin, 2012; Guillaume & Hughes, 2011; Hansen, 2012; Haraway, 2013; Hayles, 2001; 2010), and more general views on digitality and digital technologies (Galloway, 2014; Morozov, 2014a; Negroponte, 2015; Stiegler, 1998). These strands of discussion are further developed in Section 2.4, where I will discuss art and digital technologies and creative coding.

The next sections define the use of the terms 'digital', 'digitalisation' and 'digitality', concepts that are often vague or even misinterpreted. Similarly, the use and meaning of the term 'code' is clarified. After that, I broaden the discussion to the concept of post-digital. From that frame of reference I go into the concepts of code literacy, hacking, and open source, all of which are close to creative coding. Lastly, I expand the notion of digitality into the discussion of embodiment in Section 2.2.7.

2.2.1. Digital, digitalisation and digitality

The terms used to describe the diffusion of digital technologies, the phenomena of digitality, and the impacts around digitalisation are often ambiguous. It is thus worth defining the concepts around the 'digital' and making a distinction between the digital as an aspect of a thing or technology, digitalisation as a phenomenon or trend, and digitality as a condition of the digital world.

Digital

The term 'digital' has its origins in the Latin word *digitalis* and refers to digits. 'Digital' is something that is discrete in contrast to being continuous. In information technology, the term digital refers to the binary number system, which was adopted in the mid-20th century as a primary system of representation for digital computers (Ceruzzi, 2012; Steiner, 2013). 'Binary' itself simply refers to a numerical system with the base of two, which in digital technologies is prominently presented as ones and zeros. The binary system, together with the logical framework built on top of it, can be understood as the digital computer. It is noteworthy that the digital system enabled the ability to reprogram and update a computer without physically changing it, which could be seen as one of the most significant breakthroughs and characteristics of digital machines (Ceruzzi, 2012). The switch to digital technologies allowed for the rampant innovation and growth, starting from the 1940s, of what could be described as the 'digital age' (Ceruzzi, 2012).

'Digital' has also been seen to oppose 'analogue' (Galloway, 2014). Conceptually, one could see digital as one dividing into two and analogue as two becoming one: in other words, digital "describes processes of distinction or decision" and "analogue describes processes of integration or proportion" (Galloway, 2014, p. xxix). A straightforward practical example would be the difference between analogue and digital music: an analogue recording or live music is a physical event whereas digital music, a CD, or a digital music file on a computer, is a symbolic representation of the music, a combination of choices (Rushkoff, 2010). Rushkoff (2010) explains:

> "A CD, on the other hand, is not a physical artifact but a symbolic representation. It's more like text than it is like sound. A computer is programmed to measure various parameters of the sound coming from a musician's instrument. The computer assigns numerical values, many times a second, to the sound in an effort to represent it mathematically. Once the numerical—or "digital"—equivalent of the recording is quantified, it can be transferred to another computer, which then synthesizes the music from scratch based on those numbers.
> The analog recording is a physical impression, while the digital recording is a series of choices. The former is as smooth and continuous as real time; the latter is a series of numerical snapshots. The record has as much fidelity as the materials will allow. The CD has as much fidelity as the people programming its creation thought to allow. The numbers used to represent the song—the digital file—is perfect, at least on its own terms." (Rushkoff, 2010, Kindle Locations 532-539)

As Rushkoff describes, digital, on its own terms, is a perfect copy, and one of the advantages of the digital is the possibility and the ease of creating 'perfect' copies and distributing them. On the other hand, the perfectness is accomplished through making decisions which create distinctions, which can on their own affect the whole comprehension of the digital (Rushkoff, 2010).

Moreover, it should be noted that the term digital refers in this dissertation to the system digital technologies use. 'Digital' itself could be considered as any discrete system, and thus digital systems can be seen throughout history (Berry & Dieter, 2015; Petzold, 1999). Furthermore, it should be pointed out that the division between digital and analogue, or digital and physical, is not clear-cut. For instance, Latour questions the dissection by emphasising the materiality of the digital, as well as the complex relationship between digital and analogue, describing the analogue, material underpinnings of digital through the digital device's material operational structures as well as the digital's relationship to a socio-technological environment (Berry & Dieter, 2015; Latour, 2014). However, Berry and Dieter point out that "Latour is perhaps too accepting of the materiality of a representation of the materiality of computation. Indeed, this causes him to miss the aspect by which, although not immaterial, the digital is constituted through a complex series of abstraction layers which actually do enable programmers to work and code in an abstract machine disconnected in a logical sense from the materiality of the underlying silicon" (Berry & Dieter, 2015, p. 46). In sum, the term 'digital' presents the

coded binary structures of the digital technologies which are abstract as well as bound to a material instantiation. For the creative coding discussion, the Latourian insight on the ubiquitousness of the complex relationships between the digital and the analogue is of particular value.

Digitalisation and digitality

Digitalisation refers to the actions of transforming various previously physical or analogue actions into universal digital data systems. The progress in digitalisation has led to extensive and diverse speculation about the future of society and culture. Digitalisation – often very loosely defined – is commonly referred to as one of the megatrends shaping futures (Ailisto et al., 2016).

Digitalisation is a key motivation for the concept of digitality. Negroponte wrote in his book *Being Digital* (originally published in 1995) that the "change from atoms to bits is irrevocable and unstoppable" (Negroponte, 2015), arguing that everything that can be digitised will be digitised. Negroponte defines digitality as a concept referring to living in a digital and digitised culture (Negroponte, 2015). Digitality thus refers not just to the philosophical-mathematical system, nor to the fundamental technological aspects built on top of a binary structure, but also to the effects digital technologies have on our society. These issues are often intertwined with technological inventions, but are not always a direct consequence of them. For example, the rapid development of the Internet caused many theorists to proclaim that the Internet would democratise our society in unforeseen ways (Dreyfus, 2008; Morozov, 2014a; Negroponte, 2015; Rushkoff, 2010). Another, related, example is how digital technologies enabled the gathering and transcoding of various signals into one universal digital signal now widely referred to as data. One digital system can be used to represent images, sound, motion, text, etc. – it is all just data. Moreover, thanks to the Internet it is possible to freely distribute and copy data without loss of quality and (almost) without cost (Dreyfus, 2008; Negroponte, 2015; Petzold, 1999). Thus, 'digitality' can be seen as a more cultural and societal way of looking at the phenomena related to the 'digital', whereas 'digitalisation' can be roughly interpreted as the process of transcribing everything that is possible to transcribe into the digital format.

2.2.2. Code

Code in this research is defined in general terms as digital language, with a set of assumptions about the user and the world. Code is the medium used to create programs that control the wide array of digital devices, from automated factories to mobile phones, and from smart home appliances to large server farms providing cloud services. Code represents the set of instructions in the languages on which computers can operate. Computer languages vary from lower-level to higher-level languages. Lower-level languages are closer to the binary logic that computers use on the implementation level, while more complex, higher-level languages are easier for humans to write and read (Petzold,

1999). Whatever the language is, in the end all of these languages are compiled back into a binary form.

Code is the heart of every digital technology and substantially shapes its behaviour. Code enables programming, reprogramming, updating, and hacking to happen almost without physical interference (Berry, 2016; Ceruzzi, 2012). Coding is the act of writing code and building programs, which includes making implicit and explicit choices about the purpose, framing, and scope of the program. In sum, code, in this dissertation, refers to the principles and choices made in creating programs, and is not restricted to any specific programming language. Section 2.2.4. includes a table presenting different views on code based on the first article in this dissertation.

2.2.3. The post-digital era

The concept of post-digital is used in this dissertation to describe the current state of progress of digitalisation. Digital technologies are entangled in the structures of society in many different, complex, and even contradictory ways. The information society could even be seen as a society that is dependent on the computation of information, emphasising the role digital technologies have in society (Berry, 2016).

The origins of the term 'post-digital' can be traced to discussions around art in the post-digital age, particularly digital music (Cascone, 2000). From a wider perspective, the notion of post-digital can be attached to the idea of digital technologies being so common and taken for granted that digital is inevitably mixed with other aspects of everyday life (Alexenberg, 2011). In addition, 'post-digital' has been linked to Negroponte's ideas of the digital revolution, and moreover to the stage when the digital revolution is over (Negroponte, 2015; Tinworth, 2012; Wired Staff, 1998).

Furthermore, digital technologies should not be looked at as objects, or end points of human action, but as actors in constant communication with each other: non-human and human (Berry, 2016; Hayles, 2010). Thus, digital technologies could be seen as streams moving from one digital device to another, also without human involvement, giving agency to non-human objects. Berry calls this constant stream of data the 'everyday computational' (Berry, 2016). 'Everyday computational' refers to the ubiquitous nature of digital technologies, but also to how digital technologies mediate and "mediate the mediation":

> "If we consider the digital representation of a microbe, for example, there is a translation from a physical analogue microbe via a sensitive detector called an analogue-to-digital convertor, which provides a conversion to a digital form. This is then stored within the computer memory as a series of digital data points, a stream of numbers. These in turn can be processed and manipulated in a variety of ways by the computer, for example magnified, colour corrected, or analysed computationally to look for patterns. This new processed representation as a stream of numbers is then finally translated back onto the computer screen for the user and rendered as a screenic image. Of course, there is also the possibility of further interaction from the user to manipulate the data. However,

> at every stage of the process the user is reliant on the software to mediate this mediation as there is no other access to the data nor the transformations. This demonstrates the double mediation which makes the user increasingly reliant on the screen image that the computer produces, but also renders them powerless to prevent the introduction of errors and mistakes (unless they have access to the computer code)." (Berry, 2016, p.16)

The example Berry gives highlights the sometimes almost hidden roles digital technologies have in everyday life. One of the aspects of post-digital is digital technologies' 'everydayness' (Wired Staff, 1998) in which digital technologies blend in to become a non-issue. Florian Cramer takes the example of an Internet meme of a hipster sitting on park bench, writing on a mechanical typewriter, as an example of post-digital: no more does the choice to write with a mechanical typewriter implicate one as being old-fashioned, but a delicate choice (Berry & Dieter, 2015) (Chapter 1).

However, the term post-digital does not imply that the era of digitalisation is over: rather, it is a continuation in a new form. Cramer points out that post-digital should not be understood in the sense of 'post', after, something, but in a similar sense as the way we understand post-punk, post-communism, post-feminism or even post-apocalyptic. As such, post-digital implies that digitalisation should not be looked at as a linear progression of society becoming ever more digitalised, but as a cultural shift or mutation, where digitalisation has transformed our culture, communication, infrastructure, economy, and politics in a significant way and continues to do so (Berry & Dieter, 2015).

2.2.4. Code literacy

One of the issues of the post-digital era where computer code mediates most of our actions is the challenge of inequality: the so-called digital divide, or digital differentiation (Peter & Valkenburg, 2006), which formerly implied the distinction between those who have access to the Internet and those who do not (Mehra, Merkel, & Bishop, 2004), and can now be seen as the divide between those who understand digital technologies and those who do not (Baurlein, 2011). It should be noted that the divide here is not necessarily geographical or even socio-economic, as was implied with the digital divide. The idea of code literacy stems from the idea that to understand and participate in the post-digital era, an understanding of code is required (Berry, 2016; Marino, 2006; Rushkoff, 2012).

In general, code literacy can be understood as a one type of literacy: the ability to read and write code (Berry, 2016; Marino, 2006; Rushkoff, 2012). The use of the concept literacy implies that instead of mastering programming and becoming a developer by profession, one can navigate and comprehend the structures of the digital society. Many countries have in recent years introduced, or reintroduced, programming into the basic curricula in primary and secondary schools (Dredge, 2014; Group, 2014; Mykkänen & Liukas, 2014; "National STEM Centre", 2015; Pollari, 2014; "STEM to STEAM", 2016;

Toikkanen, 2015), with the goal of providing students with a fundamental understanding of code.

However, the understanding of the meaning of code literacy is convoluted. From one perspective, code literacy is understood as teaching the basics of programming and thus developing mathematical and logical skills (Mykkänen & Liukas, 2014; Pollari, 2014). Such thinking promotes the importance of understanding the logics and algorithmic processes of digital technologies, and is sometimes defined as computational thinking (Bers, Flannery, Kazakoff, & Sullivan, 2014.; Wing, 2006) or algorithmic thinking (Alano et al., 2016).

Nevertheless, seen from another perspective, the understanding of the functionality of code may not be enough if it is not linked to a more larger understanding of the role digital technologies have in society (Saariketo, 2015; 2017). Moreover, learning to code in itself is related to commercial, political, and societal structures (Williamson, 2015). For instance, code in itself is never value-free; rather, it widely reflects both the conscious and subliminal values of the programmer, software company or society's understanding of good code. Digital technology's operating models are not immutable laws of nature, but rather flexible models that are designed and controlled by humans (Lessig, 1999; 2009).

Furthermore, digital technologies, and the code running them, have biases and limitations that to some extent define how the code should operate and even what kinds of programs it is possible to execute (Dreyfus, 2008; Lanier, 2010; Rushkoff, 2010). As an example, the binary system inherent in all digital technologies presents a very different, discrete, world than the physical world (Rushkoff, 2010; 2013). These biases can in themselves have large-scale effects on both the individual and the societal level (Rushkoff, 2013; Turkle, 2011; Wajcman, 2014).

Understanding code literacy from a wider perspective connects code literacy with the larger frameworks of society, politics, and the economy as well as culture. Seen from this angle, code literacy is not about teaching and learning basic programming skills, but rather a skill of being able to understand the contexts of the code. In this way, code literacy could be likened to the way in which media literacies encourage a critical comprehension of the mediated world (Kupiainen, 2005; Mitchell & Hansen, 2010; Saariketo, 2015, 2017).

Another perspective, similar to code literacy, is offered by what Knobel and Lankshear call 'New Literacy' (2007). Here, code is understood as an actionable literacy that allows for building various kinds of media experiences that "involve different kinds of values, emphases, priorities, perspectives, orientations and sensibilities from those that typify conventional literacy practices that became established during the era of print and analogue forms of representation and, in some cases, even earlier" (2007, p. 9).

Code literacy could be seen as a critical and empowering method: in the same way that technology is not value-free, but intertwined and developed within our society and its economic, politic, and cultural constructs (König et al., 1985), digital technologies and code do not reflect an objective truth about the world. Instead, code constructs laws in the digital realm. Without understanding how these laws are formed, we are not able to fully participate in the

discourse of our digital life (Giroux, 2011; Lessig, 1999; 2009; Rushkoff, 2010). Furthermore, discussion around the ramifications of technologies is crucial, as technology tends to convert social, scientific, governmental and human difficulties into technical difficulties (Williamson, 2015).

In this dissertation, I propose code literacy as a way to participate in the discussion around the effects of digital technologies on society. Thus, the understanding of code literacy can be seen to be linked not only to Rushkoff's concept of code literacy, but more broadly to societal, educational, and philosophical studies of digital technology. In Article 1, I present a metaphorical view of code as a method to understand and discuss the differing perspectives of code. The metaphors used to understand what code is (machine, organism, brain, flux and transformation, culture, political system, psychic prison, an instrument of domination and carnival) are divided into four paradigms (functional, interpretive, emancipatory, and post-modern) that aim to structure the discussion around code into a more coherent one. The metaphors used are based on Morgan's (2006, originally published 1986) work in management and organisational studies and Jackson and Keys work in systems thinking (1984). Using metaphors can help to understand different viewpoints and understand abstract concepts more clearly (Lakoff & Johnson, 2008). Table 1 shows the metaphors and how they present different viewpoints of code.

In sum, code literacy can be seen as a way to understand the complex, intertwined relations between digital technologies and individuals as well as with society. Code, like any technology, influences society (Dyson et al., 2009; König et al., 1985) and is under the effect of the prevailing culture, economy, and politics. Moreover, the ubiquitousness of digital technologies and the ease of distributing new code constantly offers solutions for problems that would require larger societal discussions. Uber, for instance, disrupted the taxi industry with its application and made it easier to order a ride, but at the same time weakened taxi drivers' social security and rights (Bercovici, 2014; Morozov, 2014a; Stallman, 2014; Steve, 2015).

2.2.5. Hacking

The term 'hacker' originates from a small group of technology enthusiasts based at the MIT in the 1950s. This group adopted the term to differentiate themselves from their more considerate and conservative peers (Levy, 2010; Peters & Coleman, 2016). A hacker was someone who could disregard rules if they constrained creativity and invention. Hacking thus was an activity to learn and modify –hack – machines (and software) by opening them, as a learning-by-doing process (Coleman, 2013; Martinez & Stager, 2013; Peters & Coleman, 2016). Nowadays the use of the term hacker or hacking has exploded, and become vague, signifying both negative and positive connotations (Moilanen, 2017; Peters & Coleman, 2016). Websites offer lifehacks (i.e. www.lifehacker.com) to make life easier, popular culture presents hackers as criminals or geniuses (Coleman, 2013; Peters & Coleman, 2016), industries from biology to education arrange hackathons to come up with novel solutions (Irani, 2015; Moilanen, 2017; Peters & Coleman, 2016; Williamson, 2016), and

criminals hack everything digital from computers to cars (Carr, 2014; Vallance, 2015), whereas whistle-blowers have shown us that governments hack foreigners as well as their own citizens (Coleman, 2013; Kuehn, 2016; Morozov, 2014a; Peters & Coleman, 2016).

Figure 2. Hacking described (source: https://twitter.com/4ever_waiting/status/820791060465143809)

Still, hacking has a significant role in relation to digital technology and its societal and cultural movements, such as code literacy, the maker movement, or creative coding. The hacker ethos, a way of finding creative and novel ways to fix or circumvent a problem, might be the common thread connecting these different uses of hacking. The hacker ethos is illustrated in Figure 2, a viral tweet from January 2017 (https://twitter.com/4ever_waiting/status/820791060465143809). The picture shows how the child 'hacked' her mom's rules of not eating while watching a tablet. The picture highlights both the creativity, or cleverness, of hacking, but also the humour, an innate property of hacker culture (Coleman, 2013; Peters & Coleman, 2016).

Hacking also connotes stances other than the clever or creative bypassing of obstacles. Coleman points out that hacking is attached to craftsmanship as well as to political ideologies. Or, as Coleman suggests, often hacking combines humour, cleverness, political ideologies and craft:

> "Building a 3D printer that can replicate itself; stealing a botnet—an army of zombie computers—to blast a website for a political distributed denial-of-service (DDoS) campaign; inventing a license called copyleft that aims to guarantee openness of distribution by redeploying the logic inherent to copyright itself; showcasing a robot that mixes cocktails at a scientific-geek festival devoted entirely to, well, the art of cocktail robotics; inventing a programming language called Brainfuck which, as you might infer, is designed to humorously mess with people's heads; the list goes on." (Peters & Coleman, 2016, p. 358-359)

Hacking involves a sense of DIY (Do-It-Yourself) attitude together with enthusiasm towards making. Furthermore, hacking in itself incorporates aesthetic values, from beautiful code to the appreciation of craftsmanship (Coleman,

2013). In *Hackers*, a famous book from 1984, Levy describes this interest in DIY and crafts as a process of learning by doing:

> "Hackers believe that essential lessons can be learned about the systems – about the world – from taking things apart, seeing how they work, and using this knowledge to create new and even more interesting things." (Levy, 2010, p. 27–36)

As such, hacking can be seen to be related to the maker movement, or as some suggest, the maker movement is even the continuation of the hacker ethos (Cuartielles, Bean, & Rosner, 2015; Hertz, 2015). Hackerspaces, communal places offering tools and opportunities for peer learning, are similar to maker spaces or fab labs (Lindtner & Li, 2012; Martinez & Stager, 2013; Moilanen, 2017). Coleman even sees similarities between historical guilds of artisans and the free and open source projects of hackers (Peters & Coleman, 2016). Moilanen suggests that open source projects, as well as the advance of the maker movement, can also be seen to have shifted public opinion of hackers as criminals to hacking as a virtue (Moilanen, 2017, p. 46).

The political dimension of hacking stems from hacker ethics – a mix of aesthetic and pragmatic imperatives that can be summarised as sharing, openness, decentralisation, free access to computers and world improvement (Levy, 2010). Hackers are also active in many of the movements concerning digital technologies such as FLOSS (Free/Libre and open software) and EFF (Electronic Frontier Foundation). Coleman connects these ethical values to the cultural interpretation of liberalism: "on the importance of knowledge, self-cultivation, and self-expression as well as the vital locus of freedom" (Coleman, 2013, p. 3). However, Coleman points out that the political views of hackers are not united, but rather varied. For instance, free software hackers form a more political and radical opinion of the ownership of code than open source hackers, and other strands detach themselves from libertarian views by their civil disobedience and more radical activism (Assange et al., 2012; Berry, 2008; Coleman, 2013; Peters & Coleman, 2016; Stallman, Gay, & Lessig, 2009). However, Morozov, for instance, has critiqued that hackers are close to "the Californian ideology" – "a mix of cybernetics, free market economics, and counter-culture" (Barbrook & Cameron, 1996; Peters & Coleman, 2016).

The importance of hacking in this dissertation stems partly from its connections to the maker movement, arts, and ethical values. Seeing code as an art form (Coleman, 2013), hacking as learning by doing (Martinez & Stager, 2013; Peters & Coleman, 2016), or hacking as a critical thinking (Peters & Coleman, 2016; Söderberg, 2015) all link hacking closely to code literacy as well as to the creative use of digital technologies. Another aspect that emerges in the context of this dissertation is the embodied aspect of making and hacking: how are these practices connected to the embodied perspective of digitality? For instance, DeLanda quotes Richard Stallman, the creator of the Free Software Foundation, on discussion of the problematics of proprietary, closed code:

Metaphor	Description of code	Purpose of code	Example
Machine	Code is a linear sequence of commands that is input into a machine	To control a machine	Algorithms, code listings
Organism	Code is a set of objects that represent different parts of a program	To create functionality, to interact	Object-oriented programming
Brain	Code is the intelligence of man-made systems	To create new information, to learn	Cloud computing, artificial intelligence
Flux and transformation	Code is the process that creates changes in man-made systems	To create change, to create structure	Software as life changer
Culture	Code is a way of thinking and understanding the world	To connect and create a community	Free software foundation, hacker ethics, hacker culture
Political system	Code is a statement and a tool to shape the world	To establish a new form of society	Code as political construct. Internet
Psychic prison	Code is a system which requires people to adapt to it	To shape people	Filter bubble
Instrument of domination	Code is a tool for domination	To control people	Data as a source of power
Carnival	Code is a tool for art and creativity	To challenge existing mind-sets, to open up discussion	Creative coding

Table 1. Metaphors for understanding the nature and purpose of code

"He [Stallman] acknowledges the traditional way of posing the problem but adds that in addition to the material social waste there is a 'psychosocial damage' associated with intellectual property, an erosion of the community value of helping one's neighbor" (2001, p. 99).

Such ethical and aesthetical responsibility can be connected to the view of embodiment as discussed in Article 2 and even to the concept of digi-grasping as formed in Article 3. Some of these questions are presented in the Discussion (Chapter 4) in the context of digi-grasping.

2.2.6. FLOSS and OSHW

Whereas 'hacker' and 'hacking' are more broad concepts implying certain attitudes or even ideologies towards digital technologies, Free/Libre and Open Source Software (FLOSS) and Open Source HardWare (OSHW) indicate a more defined standpoint on digital technologies[1]. Generally, FLOSS is concerned with the rights and freedoms of the software user (Coleman, 2013; Feller et al., 2005; Söderberg, 2015; Välimäki, 2005) whereas OSHW is the hardware equivalent, considering the rights and freedoms for the digital hardware running the software (Open Source Hardware Association, 2012).

The importance of FLOSS can be seen in how it defends the rights and prospects of the users of the software. In general, this can be summed up as people's rights to use software, modify the software and redistribute the software (Feller et al., 2005). The Free Software Foundation (FSF) has a more explicit version of these rights:

> "The freedom to run the program as you wish, for any purpose (freedom 0).
>
> The freedom to study how the program works, and change it, so it does your computing as you wish (freedom 1).
>
> Access to the source code is a precondition for this.
>
> The freedom to redistribute copies so you can help your neighbor (freedom 2).
>
> The freedom to distribute copies of your modified versions to others (freedom 3). By doing this, you can give the whole community a chance to benefit from your changes.
>
> Access to the source code is a precondition for this (“Free software is a matter of liberty, not price)" (Free Software Foundation, n.d.)

In both cases, the general point can be seen in the ability to read how the software is built and then build on top of that (Feller et al., 2005; Söderberg, 2015). As such, FLOSS can be seen to go against capitalistic ideas of ownership (Berry, 2008; Söderberg, 2015). The ability to see how a program is built is not

[1] As a side point, the FLOSS movement is also a generalisation, combining free software and open source ideologies. For some, the difference is a significant political issue, whereas others see it as a matter of emphasis (Feller et al., 2005; Free Software Foundation, n.d.; Peters & Coleman, 2016; Stallman et al., 2002). While both movements emphasise freedom, open source ideology values the freedom to choose how to use software whereas free software ideology is concerned with the freedom of the software itself. Because of this, open source ideology can be seen to be more in line with neoliberal values and free software as going against it (Berry, 2008; Peters & Coleman, 2016). This dissertation uses the term FLOSS as a general concept indicating the ability to read and use another people’s code.

only a democratic right, but a privacy issue as well. Without seeing how the software was written, we have no means of knowing what the software does (Feller et al., 2005; Söderberg, 2015; Stallman et al., 2002; Vadén, 2005). The abilities to read, modify and share code can also be seen as necessary premises for code literacy (Berry, 2016; Stallman et al., 2002) as well as to creating art with software. As an example, machine learning or other complex algorithms might be out of reach for the normal creative user, but with openly usable code, anyone can benefit from it (see, for example https://aiexperiments.withgoogle.com/).

Open Source Hardware aims to make the production of digital hardware more open (Oshwa.org, n.d.). This means sharing the technical details of the hardware: circuit design and diagrams, and in some cases also software, as many digital components have code inside them already (Stallman, 2015). One example of open source hardware is the Arduino microcontroller (arduino.cc), which is a programmable computer popular among hackers, makers, and artists (Arduino Music and Audio Projects, 2015; Barrett, 2013; Cook, 2015; Kohtala, 2016; Martinez & Stager, 2013; Sirkin, Martelaro, & Ju, 2017). The open design of the Arduino has enabled others to modify the microcontroller to fit in their projects, from 3D-printers to wearable electronic platforms (Buechley & Perner-Wilson, 2012; Mellis & Buechley, 2014; 2012; Moilanen, 2017).

2.2.7. The body in digitality

One of the qualities, and perplexing problems, of digital technology has been the separation of mind from body: digital technologies function on the intellectual level, engaging the mind of the person, while leaving the body standing in front of the screen, without much physical activity. The development of the Internet, virtual reality, and artificial intelligence have further separated and complicated the relation between digital technology and the body. The Internet has enabled new ways of communication, from social media to virtual worlds such as Second Life, or more recently WoW (World of Warcraft). Furthermore, smart devices, from mobile phones to watches, and other smart appliances, augment physical reality with digital appendices in various ways (see for example, Kholeif, 2014; Makridakis, 2017; McReynolds et al., 2017; Uricchio, 2011). In essence, these developments in digital technology offer real-time communication with other people without physical interaction.

However, a sharp separation of mind from the body is not new, but a reoccurring theme in the whole of western civilisation, from Plato's cave depiction to Christianity to Descartes' dualism (Dreyfus, 2008). Digital technology offers a new platform for these ideas, from the fantasy-filled thoughts of singularity, through artificial intelligence, to more everyday questions of how digital environments and interactions compare to physical ones. For example, Dreyfus famously critiqued the use of digital platforms in communication and education (Dreyfus, 2008), Turkle has written on the psychological effects of the Internet (Turkle, 2011; 2015) and Rushkoff, Lanier and Morozov, among others have noted the problematics of replacing physical frameworks with digital

ones (Lanier, 2010; Morozov, 2014a; 2015; Rushkoff, 2013). In essence, the notion of the body in digitality is under constant redefinition (Berry, 2016; Guillaume & Hughes, 2011). On one side, the body can be seen only as an instrument, a shell for the mind, as is the case in Gibson's Neuromancer (1984) or Kurzweil's and Moravec's futuristic visions of downloading a mind into a computer (Kurzweil, 2005; Moravec, 1988; 1997). On the other hand, the body is seen as an integral part of digitality as a place for knowledge-making (Berry, 2016; Dreyfus, 2008) or as a cyborg, a hybrid of flesh and technology (Dahlin, 2012; Haraway, 2013; Hayles, 2010). Furthermore, Hansen (2006) has studied the relationship between the phenomenology of the body and digital code.

Virtual reality, in the form of virtual environments offered through the screen, but also as integrated virtual systems, commonly consisting of a headset and pointing device, have awakened an exciting discourse on digitality and embodiment (see for instance, Hansen, 2012; Lanier, 2017; Munster, 2006; Nash, 2015). Nash (2015), considers virtual environments as post-convergent, containing all prior media as content. Furthermore, Nash and Munster (2006) discuss digital code in the context of Deleuze and Guattari's assemblage (1988), further refined and used in social contexts by DeLanda (2006). The concept of assemblage offers an alternative way of looking at social or any other constructs. Instead of understanding the world as consisting of distinct objects or things, the assemblage theory emphasises the fluidity, exchangeability, and multiple functionalities of constructs. From that perspective, the assemblage of code can be seen as a whole, consisting of, for instance, the computing device, the code running it, the data being processed and communicated, and the actor (human or non-human) operating it. The benefit of such a perspective is to present the intertwined nature of the code, not only in terms of social, economic, political, or cultural constructs but also the fluidity and dynamic nature of the code as well as the materiality of the code, the way digital interacts with various other, also embodied, elements, and to digitality's role or relationship with embodiment. Assemblage theory is further discussed in the Chapter 4. However, a more in-depth discussion on these perspectives of virtual environments and embodiment are out of the scope of this research.

This dissertation is more focused on these embodied views of digitality, and its significance for creative coding, both as an art medium and as educational method. As such, some of the complex problems, for instance in post-human discourse, are of importance, but at the same time out of limits for this research.

2.3. Making by hand

> *"The body is our general medium for having a world."*
> *(Merleau-Ponty, 2012)*
>
> *"If you can't open it you don't own it" (Maker movement's motto)*

Making is essential for humans, states Finnish craft professor Kojonkoski-Rännäli: "through making one materialises her existence" (Kojonkoski-Rännäli, 2014, p. 36). In other words, doing by hand has a great relevance to com-

prehending self and the surrounding world (Kojonkoski-Rännäli, 1995; 2014). Kojonkoski-Rännäli elaborates that making in this sense refers to the intentional activity in which one realises one's aims and objectives. As such, making can be seen from the point of Heidegger's phenomenological theory: the mode by which humans exist in the world is dwelling (*wohnen*). This existing, living, is realised through making (*bauen*). Hence, argues Kojonkoski-Rännäli, doing by hand is one of the core components of existing in the world (Heidegger, 2009; Kojonkoski-Rännäli, 1995; 2014). The phenomenological meaning of making by hand can be extended to Merleau-Ponty's theory of embodiment: making by hand predates rational knowledge, through the act of making, one grasps and understands something before knowing it (Kojonkoski-Rännäli, 1998; Merleau-Ponty, 2012). In essence, Kojonkoski-Rännäli sees making by hand as essential to human existence: making by hand is a bodily experience that produces knowledge as well as emotional and ethical relationships between the self and the surrounding world (Kojonkoski-Rännäli, 1995; 2014).

Kojonkoski-Rännäli's understanding of making by hand bears similarities to other researchers' comprehension of making by hand as an important factor for humans' and nature's well-being, as well as the development of society and culture (Gauntlett, 2013). Thus, making by hand should not only be understood narrowly as a creation of artefacts but as an inquiry as well as a belonging to the surrounding world (Hertz, 2015; Kojonkoski-Rännäli, 2006; 2014; Ratto, 2011; Sennett, 2008). In fact, in the age of automation, the significance of craft is often seen as a method for personal development and well-being (Groth, 2017; Halverson & Sheridan, 2014; Koskinen, Seitamaa-Hakkarainen, & Hakkarainen, 2015; Veeber et al., 2015) or as Kojonkoski-Rännäli expresses it, making by hand is edifying work (Kojonkoski-Rännäli, 2014, p. 50).

Ratto proposes the term 'critical making' as a concept signifying the value of making by hand in a technological society (Ratto, 2011). Critical making joins two distinct traditions: conceptual and linguistic critical thinking with physical making (Ratto, 2011, p. 2). Ratto sees the value of critical making in how it uses making as a way to acquire knowledge of, and criticism towards, digital technology. Furthermore, Ratto argues that social research on technology has been twofold: one side asserts that technology is inhibiting and reduces human action, whereas the other side insists on technology's liberating aspects (Ratto, 2011). Critical making, on the other hand, uses technology as a means to gain critical understanding of technology (Hertz, 2015; Ratto, 2011).

In this research, the importance of making by hand is understood in the context of phenomenology, as intentional making that, besides creating an artefact, forms the maker's qualities and their knowledge of the world. Making by hand is seen as a critical activity towards the digitalised world. Furthermore, the emphasis on making by hand lies in the process, and not in the creation of an artefact (Kojonkoski-Rännäli, 1995; 2014; Konopasky & Sheridan, 2015; Veeber et al., 2015).

2.3.1. The Maker movement

The maker movement is a broad cultural movement that focuses on the resurgence of making by hand coupled with the interest in the new digital technologies for production and sharing (Anderson, 2012; Blikstein & Krannich, 2013; Dougherty, 2012b; Halverson & Sheridan, 2014; Hatch, 2013; Martinez & Stager, 2013). However, the conception of the maker movement is segmented: it is seen as an economic remedy (Anderson, 2012; Lang, 2013), as a cultural movement (Breeding, 2012; Fox, Ulgado, & Rosner, 2015; Halverson & Sheridan, 2014), and as a new pedagogical method (Buechley & Perner-Wilson, 2012; Halverson & Sheridan, 2014; Martinez & Stager, 2013).

The maker movement is often associated with the rekindled interest in hardware design and manufacturing, accompanied by the proliferation of inexpensive production tools (Anderson, 2012; Halverson & Sheridan, 2014). The Internet has helped in expanding the maker movement into a global movement, often connecting people in ways that otherwise would have been unlikely (Anderson, 2012; Martinez & Stager, 2013). Chris Anderson, a former editor-in-chief of *Wired* magazine and the author of *Makers: The New Industrial Revolution*, calls the maker movement a new industrial revolution which happens "when the web generation turns to the real world" (Anderson, 2012, p. 42). As such, the maker movement is celebrated as a new way to create more ideas and products that otherwise would not have been possible (Anderson, 2012; Buechley, 2014; Hatch, 2013; MacMillan, 2012; Martinez & Stager, 2013; Mellis & Buechley, 2014).

However, to think of the maker movement merely as an interest in affordable production, novel manufacturing platforms, or creation of imaginative products is somewhat misleading. Dougherty, the founder of Make magazine – a magazine aimed at enthusiastic makers – describes makers as enthusiasts who want to explore the possibilities of both new and old technology (Dougherty, 2012b). Similarly, Martinez and Stager present the maker movement as "terribly exciting in the ways it celebrates the virtues of constructionism, even if the advocates of learning by making have no formal knowledge of theory underlying their passions" (Martinez & Stager, 2013 Kindle Location 829 of 5629). The maker movement is also seen to blend formal and informal learning. This blending can happen through the emphasis first on the making, instead of theory, as well as through using makerspaces as educational spaces (Blikstein & Krannich, 2013; Halverson & Sheridan, 2014).

The pedagogical value of the maker movement can also be perceived from the context of critical making, where the act of making affords insights into digital technology (Hertz, 2015; Ratto, 2011). The maker ethos of being able to open, upgrade or fix devices can be seen as both the DIY spirit of being able to repair devices (Dougherty, 2012a; Lang, 2013; Mellis & Buechley, 2014), and also as an empowering method (Buechley & Perner-Wilson, 2012; Mellis & Buechley, 2014). As such, the maker movement's relationship to hacking and hacker ethics becomes understandable (Fox et al., 2015; Levy, 2010; Martinez & Stager, 2013; Nagbot, 2017).

The maker movement can also be seen as a continuation, or a new version, of the 20th-century Arts & Crafts movement (Morozov, 2014b; Patokorpi, 2014). Morozov worries that the maker movement might not end up to be a significant movement but rather a fad, or even an extension of the neoliberal agenda (Morozov, 2014b). Furthermore, the maker movement has been critiqued to be aimed at white male nerds (Halverson & Sheridan, 2014), and being limited to a narrow range of the spectrum of making: robotics, electronics, and vehicles (Buechley, 2014). Despite the criticisms, the maker movement does include a diverse field of practitioners across the world, and disciplines as diverse as DIY synthetic biology and wearable electronics (Buechley & Perner-Wilson, 2012; Lindtner & Li, 2012; Mellis & Buechley, 2012; Tochetti, 2012). These different sub-cultures give the maker movement a unique twist as well as a varied character (Halverson & Sheridan, 2014). As such, the maker movement works as an interesting context for making in the digital era (Halverson & Sheridan, 2014).

2.4. Art and digitality

#!/usr/bin/perl

APPEAL:
listen (please, please);

open yourself, wide;
join (you, me),
connect (us,together),

tell me.

do something if distressed;

@dawn, dance;
@evening, sing;
read (books,$poems,stories) until peaceful;
study if able;

write me if-you-please;

sort your feelings, reset goals, seek (friends, family, anyone);

*do*not*die (like this)*
if sin abounds;

keys (hidden), open (locks, doors), tell secrets;
do not, I-beg-you, close them, yet.

accept (yourself, changes),
bind (grief, despair);

require truth, goodness if-you-will, each moment;

select (always), length (of-days)

 # listen (a perl poem)
 # Sharon Hopkins
 # rev. June 19, 1995

In this research, the view on art and digitality is twofold: first the focus is on art's relationship to digitality. The second view is a more pedagogical one, where art functions as an educational framework through which to understand digitality. The use of the concept of digitality here refers both to the digital technologies and to digitality as culture and societal phenomena. The first section, 2.4.1. briefly discusses digital art and the following one looks at educational practice through creative coding.

2.4.1. Digital art

Digital art is a diverse concept that in general implies art made with digital technologies, and can be seen to include practices such as computer art, multimedia art, virtual art, and net art, as well as being included itself in the broader term of media art, or new media art (Paul, 2008; Wolf, 2009). Moreover, the effects of increasing digitalisation can be seen in traditional art mediums as well (Bishop, 2012). In the post-digital era, digitality is so bound into everyday life that digitality has formed a new aesthetic, influencing all aspects of art-making and perceiving (Berry & Dieter, 2015). For instance, digitality has changed the ways we use, comprehend and look at photographs (Berry & Dieter, 2015; N. Czegledy & Czegledy, 2000; Knochel, 2014; Manovich, 2017).

In general, artists have been quick to adopt new technologies to their work. Digital technologies and programming in the visual arts have an extensive history, originating as early as in the late 1950s (Berry, 2016; Cox, 2013; Dent, 2017; Greenberg, 2007; Rutsky, 1999; Shanken, 2001; Taylor, 2014). However, even if digital tools have found their way into the arts, it could be argued that programming and code have never become mainstream in the art world. Taylor suggests one reason for this could be the scientific and military background of digital technologies and its perceived contrast to more humanistic arts, which, at least at in the beginning of the digital era, distanced artists from digital technologies (Taylor, 2014). Jeanne Beaman, a dancer and choreographer, and a pioneer in computer dance states:

> "Most of us do not even want a machine of any kind to succeed in conceiving any art form at all. The arts are usually presented as our last refuge from the onslaughts of our whole machine civilization with its attendant pressures towards squeezing us into the straitjacket of the organized man." (Taylor, 2014, p. 5)

Such perspectives are still apparent in contemporary discussions, where, for instance, advanced algorithms, machine learning, and deep neural networks seem to advance further into the humanistic domain (Berry, 2016; Cox, 2013; Dent, 2017; Makridakis, 2017).

However, the domain of contemporary digital art is rich with genres ranging from glitch and net art to code poetry (Berry & Dieter, 2015; Conrad, 2014; Cubitt, 2007; “Source Code Poetry 2016,” 2016). For instance, esoteric.codes, a

website for programming languages intended as experiments, jokes or art presents programming languages such as TrumpScript and Oou (esoteric.codes, n.d.). TrumpScript's features include:

> "- No floating point numbers, only integers. America never does anything halfway.
> - All numbers must be strictly greater than 1 million. The small stuff is inconsequential to us.
> - There are no import statements allowed. All code has to be home-grown and American made."
> -TrumpScript also “will automatically correct Forbes’ $4.5B to $10B.”
> (http://esoteric.codes/post/137771088233/trumpscript-a-theme-language-done-right)

whereas Oou has a design goals such as "make you go out of your mind" and "alienating, intoxicating effect" (http://esoteric.codes/post/139115313348/oou-the-insane-language).

Programming, as with any artistic medium, offers a unique set of tools that can express views that otherwise might be difficult (Cox, 2013) Cubitt states that:

> "It is my contention that art practice acts not simply as a diagnostic device for the contemporary but as antennae sampling the likely directions of near and further future shifts in the social, cultural, economic and political formation of society." (Cubitt, 2007, p. 2)

It should also be noted that programming as art can also be viewed from the scientific perspective. In *Computer Programming as an Art,* Knuth argues for the teaching of beautiful code, the importance and value of writing aesthetically pleasing code, as well as the usefulness of attributes such as creativity and exploring usually credited to the arts (Knuth, 2007).

The ubiquitousness of digital technologies cast the relationship art has with digitality into a different light. Digitality has progressed from exceptional to ordinary, where art practice, both the creation of and looking at art, are transformed and comprehended through digitality (Berry & Dieter, 2015). Knochel and Patton see the value of digital art as 'boundary objects' and 'boundary shifters', where art crosses social worlds and transforms them (Knochel & Patton, 2015). Digital art in this sense can be understood as post-digital, post-Internet art, where art-making is interpreting and transcribing the digitality (Berry & Dieter, 2015; Debatty, 2008; Vierkant, 2010).

2.4.2. Creative coding

Creative coding could be described as programming where expression is more important than function (PBS, 2013). Knochel and Patton liken creative coding to any other practice in the art studio: by learning the basics of the medium one can start to express and even break the rules (Knochel & Patton, 2015). Some programming languages, programming environments, and devices have

already been built specially for creative coding. For instance, projects like the Processing programming language (www.processing.org), Open Frameworks creative coding framework (http://www.openframeworks.cc), Arduino microcontroller (arduino.cc) and Raspberry Pi computer (www.rasperrypi.org) emphasise the creative use of digital technologies. In sum, these platforms offer an opportunity to experiment and explore programming without much technical knowledge of programming (Greenberg, 2007; Knochel & Patton, 2015; Shiffman, 2009; The Art Club, 2017).

Furthermore, creative coding expands the notion of programming from writing code to a broader artistic activity that includes code. Instead of just writing software, many projects include physical elements, electronics, sensors, and interaction with the physical world. From home-built smart home appliances to interactive and immersive art installations, creative coding uses the whole field of digital technology as its material as well as its tool. Both the platforms and programming environments, as well as the culture of creative coding, allow space for exploration and expression (Greenberg, 2007; Shiffman, 2009). Casey Reas, one of the creators of the Processing language, sees coding as a humanistic activity, as a way of thinking (Cangiano, 2016), and even as something that could be as fluid as drawing (The Art Club, 2017).

Creative code can also be seen from an art educational viewpoint as a meaning-making process, as suggested by Knochel and Patton: "However, creative code may broaden understanding of differentiated experience, contextualized meaning, and emergent behavior so important to critical thought and perform beyond instrumentality" (2015, p.12), opening the complex position of digitality in everyday life, through exploration, into a bricolage of artistic and digital technology practices. Furthermore, Knochel & Patton connect creative coding with the values of openness and remixing that further connect creative coding into the domains of FLOSS, hacker culture and code literacy. For instance, the ability to read and use others' source code both allows for the use of more advanced expressional tools (created and shared by a more experienced programmer, or by a group of programmers), but also connects creative coding to code literacy through understanding the value of open code, as well as remixing culture by using, modifying and, sharing code (Knochel & Patton, 2015; Sonvilla-Weiss, 2010).

Creative coding can also be understood in the context of the discussion of embodiment and digitality. As proposed in Article 2, hands-on digital making can deepen the connection between the doer and the digital world. Moreover, creative coding can be seen as a sense-making of the complex intertwined post-digital world. These aspects are further discussed in Chapter 4 in relation to digi-grasping.

3. Research contribution

There are four main research contributions in this dissertation. The first is the broadened framework of teaching programming. The widened perspective links programming into societal, philosophical, and cultural themes. The second is the emphasis on the importance of making by hand as a knowledge-making skill in the digitalised world. The third contribution expands on the second one, suggesting that active and empowered participation in the digitalised society requires a more embodied understanding of digitality. The fourth contribution develops creative coding as an art educational method for both understanding the digitalised world and using digital technology as an artistic medium. Together these articles answer the research question of how does art education and more specifically creative coding work as a practice to increase our comprehension of, and active participation in, the surrounding post-digital structures. In this chapter, I will describe these contributions in more detail based on the four research articles.

3.1. Metaphors of code – structuring and broadening the discussion on teaching children to code (Article 1)

The first article, written together with Dr. Mikko Dufva, takes a look at the discussion and perception of teaching programming in the basic curriculum. The aim of the article was to answer the question "how should teaching programming be understood?" (as stated in Figure 1). The background for this research was the growing interest in introducing teaching programming in primary and secondary schools in Finland and abroad. (See for example, Halinen, 2014; "National STEM Centre ", 2015; Sterling, 2015). The article concentrates on how code can be perceived and comprehended and how the comprehension of code affects the teaching of programming.

The basis for the article is the understanding of the nature of code; understanding the basics of code's technological nature, as well as the societal, economic, and cultural forces affecting the code. The understanding of the code could be translated into code literacy, meaning the ability to read and write code as well as understanding the relation code has to the larger contexts of society, culture, and economy. (Berry, 2016; Morozov, 2014a; Rushkoff, 2010; 2016).

One of the main observations in this article is that teaching children to code is currently focused too much on technology and mathematics. The article uses nine metaphors (machine, organism, brain, flux and transformation, culture, political system, psychic prison, instrument of domination, carnival) and four paradigms (functional, interpretive, emancipatory, post-modern) to open up the discussion around code and teaching programming. The benefit of these metaphors is that they support a more comprehensive and future-proof education around code and coding. For instance, the interpretative and emancipatory paradigms highlight the plurality of views and complex power structures

related to code. The benefit of comprehending teaching programming through these different perspectives is in that it can promote children's ability to understand code not only as a technical skill but also as an integral part of contemporary society and everyday life.

3.2. The Maker Movement – creating knowledge through basic intention (Article 2)

The second article moves from the inspection of code into looking at digital technologies in the context of handicraft. The article examines the maker movement and its relation to doing by hand. The research question as stated in Figure 1 was: "what can doing by hand offer to the understanding of digitality?" More specifically, the article compares Finnish craft professor Kojonkoski-Rännäli's philosophy of craft practice to the resurgent interest in making by hand brought forth, for instance, by the maker movement. Moreover, the article concentrates on Kojonkoski-Rännäli's concept of basic intention, a making that not only produces an artefact but also expands the maker's knowledge and belonging to the world around them.

The article uses theoretical research on both the maker movement and Kojonkoski-Rännäli's theories. The article situates Kojonkoski-Rännäli's theories into a larger context of craft research as well as critically examining the maker movement and its possible benefits in the context of understanding digital technologies through making. The article enforces the comprehension of doing by hand as an important skill. It suggests that combining digital technologies and doing by hand may make the doer feel more connected to the digital world. Furthermore, the article proposes that the maker movement may be thought of as a helpful educational method in combining doing by hand with digital technologies. The article also offers one perspective on the question of embodiment and digital. By understanding coding as a practice that involves the coder in the intertwined world of the digital and physical, the article suggests a phenomenological view of the way code can be seen as embodied. The theory of embodied digitality is discussed further in Article 3 and in the discussion chapter (Chapter 4).

3.3. Grasping the future of digital society (Article 3)

The third article expands on the importance of doing by hand in the digital environment. Written together with VTT (Technical Research Centre of Finland) researcher Dr. Mikko Dufva, this article suggests that the abstract nature of digitalisation leads to a detached sense of the digital surroundings. In this paper, we argue that in order to grasp the nature and future of a digitalised society, an embodied understanding of digitalisation is needed. The overarching research question in the article, as mentioned in Figure 1, is how to situate oneself in the digital world. The paper draws from theoretical research in philosophy, future studies, and cognitive research, as well from art and art research. Furthermore, the article benefits from the author's phenomenological

research in creative coding in the Arts@school-project at Martinlaakso secondary school in Vantaa, Finland.

How the digital world is experienced and perceived determines what kinds of futures can be imagined. As such, being able to situate oneself into the digital world becomes a question of empowerment and active participation in the surrounding world. Furthermore, we introduce the concept of 'digi-grasping' as a way to analyse our awareness of and involvement in the digital world. Digi-grasping refers to Merleau-Ponty's concept of grasping (Merleau-Ponty, 2012) as an activity that is intentional, but not necessarily conscious; it is possible to grasp something before knowing it. The relevance of grasping is in how it creates and shapes the knowledge of the experienced world through the body and embodied action. The body plays an important part in knowledge creation and creates knowledge that would be hard to gather otherwise (Dreyfus, 2008; Merleau-Ponty, 2012). Digi-grasping, in turn, describes active sense-making and existing in the in-between of the digital and physical world. The article describes four modes of being and doing in the digital world: ignorance, awareness, empowerment, and transformation. The analysis of digital embodiment also suggests that through being and creating in the digital domain, we attain not only knowledge but also moral and aesthetic connections to the digital world.

3.4. Creative coding at Käsityökoulu Robotti (Article 4)

The fourth article is an ethnographic study on creative coding as a teaching method. Creative coding is used as both an artistic medium and a tool for comprehending digital technologies. The research focuses on Käsityökoulu Robotti (Robotti Art & Craft School), an art school for children that focuses on the fusion of art and technology. The research spans the five years of Käsityökoulu Robotti's existence and uses questionnaires and interviews along with informal discussions, field notes, and other material to draw an image of how, first, creative coding is understood and, second, how creative coding works as an educational method. The research question as stated in Figure 1 is "how does creative coding work as a teaching method?" The research focuses on the informal education provided by Käsityökoulu Robotti, but some of the results could also be expanded to formal education.

The article broadens the concept of creative coding and suggests ways it can be used in education. The larger context is illustrated in Figure 3. Furthermore, the article maps the larger context around creative coding as a teaching method. The broader context may be beneficial in comprehending the different aspects of creative code and teaching programming. The research reveals the benefits of using an art educational approach in teaching programming. For instance, art education was perceived as giving more freedom to teaching programming or digital technologies in general. Moreover, art education was seen as allowing the teacher as well as the students to venture into digital technology without technical expertise: exploration and critical inquiry, the inherent practices in art education, were seen as major assets.

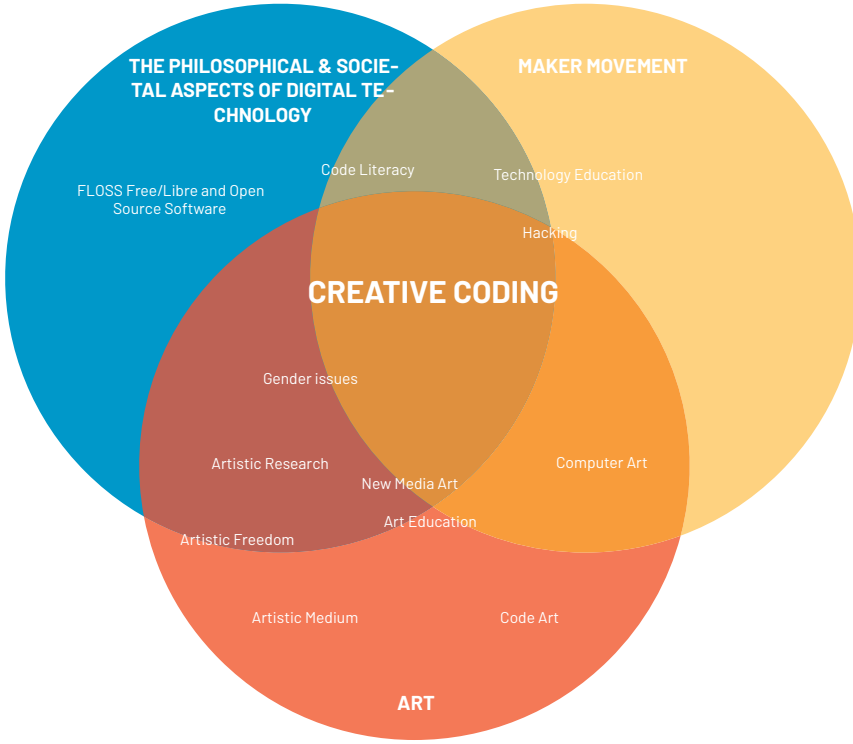


Figure 3. The larger contexts of creative coding, taken from the article 4.

3.5. Summary of results

The main research contributions derived from the four articles can be seen to create a pathway from teaching programming into using digital technologies as an educational and artistic method, to gain an understanding of digital technologies and the post-digital world. The art educational method is named creative coding, inspired by the creative coding community and indicating coding that does not necessarily need to be narrowly functional. Furthermore, the concept of creative coding is broadened to include artistic and art educational activity dealing with digital technologies. The first three articles can be seen to build a larger theoretical framework for creative coding which is then discussed in more detail in Article 4.

The dissertation also offers alternative perspectives on the digitalised world. The perspectives are first discussed in the context of code, the underlying foundation of digital technologies in Article 1. The context is then broadened in Article 3 to include the digitalised world or the in-between of the physical and digital world. These alternative perspectives bring more complex and embodied viewpoints to code as well as to digitalisation. The question of embodiment and digitality is first discussed in Article 2 through the philosophy of making by hand and then in a larger sense as embodied digitality in Article 3.

4. Discussion

> *"Muuntaessaan kokemuksiaan taideteoksiksi oppija liikkuu tiedostamattomien havaintojen ja tietoisten, käsitteellistävien toimintojen välillä."*
>
> *"By transforming experiences into art works the learner moves between subconscious cognition and conscious, conceptualising processes." (Räsänen, 2000, p. 16)*

This dissertation offers three theoretical contributions and two practical contributions to the field of digital technology, education, and art. The next section discusses the theoretical implications and the subsequent section the practical implications. I will also discuss the methodological limitations of this research as well as the possibilities for future research.

4.1. Theoretical implications

As discussed in this dissertation, digitality is essentially an unremovable part of contemporary everyday life. One of the main theoretical implications of this thesis is the importance of a broader perspective and comprehension of the role that digital technologies play in the post-digital era. The larger perspective is brought forward by three alternative theoretical methods for understanding post-digitality:

1. The use of metaphors can help to broadly observe the distinct perspectives and scopes of digital technology in contemporary society.
2. Comprehending digitality not as a detached technology, but as a process, or condition that is intertwined with everyday life. This dissertation uses the concept of digi-grasping to bring forward a more embodied understanding of digitality.
3. The act of the creative use of code can be beneficial and essential in acquiring knowledge and comprehension of digital systems.

4.1.1. Broadening the understanding of digital technology

The increasing digitalisation has come under criticism and critical research in the recent years. For instance, Morozov has critiqued the growing political and societal power that digital technology companies have gained (Morozov, 2014a; 2015; 2016; 2017), whereas others have called attention to the way individuals make use of digital devices (Rushkoff, 2013; Turkle, 2011). Turkle, as an example, has criticised bringing in machines in professions that require human interaction, such as day-care and nursing homes (Turkle, 2011). Furthermore, the post-digital condition has been researched in the humanities (Berry, 2014; Hayles, 2008; Wajcman, 2014) as well as in the arts (Berry & Dieter, 2015; Contreras-Koterbay, 2016).

However, the general comprehension and attitude towards digital technologies have broadly stayed functional: digital technologies offer services that one can use to ease or simplify certain processes (Morozov, 2014a). Similarly, the increase of digitalisation appears, for instance, as inevitable (Ailisto et al.,

2016), or as a progress, something one must get aboard (Jungner, 2015). This dissertation contributes to the discussion and comprehension of the role of digital technologies, in particular to the understanding of code, the underlying structure in digital technologies. Through the use of nine metaphors (machine, organism, brain, flux and transformation, culture, political system, psychic prison, instrument of domination, carnival) and four paradigms (functional, interpretive, emancipatory, post-modern), it offers a broader perspective on code, where code can be seen not only as a functional but as an intricate set of technological, political, ideological, economic, and cultural dimensions.

Metaphors can be beneficial tools in the comprehension of abstract or complicated concepts (Lakoff & Johnson, 2008), whereas paradigms, a set of assumptions, ideas, and beliefs (Kuhn, 1970), can help to situate different themes into larger frames of reference. For instance, understanding programming through a functionalist paradigm includes the understanding of code as a way to give instructions to a computer, but also as a way to instruct the computer to learn from large sets of data. However, neither of these views question the context of the code: programming is still a function to reach a goal, and not, for instance, a questioning of the ethical or cultural dimensions of the code. Here, the use of paradigms and metaphors can help in comprehending these different dimensions of code.

The understanding and scope of code are becoming of vital importance in the context of teaching programming in the basic curriculum. Seeing code exclusively from the perspective of the dominant functionalist paradigm disregards substantial parts of what code is. The use of metaphors can be an effective heuristic in illustrating alternative viewpoints. Thus, teaching programming can be seen as a useful logical skill, but also as a creative tool, and furthermore as a competence to critically inspect code in its multiple effects and roles. For instance, teaching programming could integrate mathematics and arts, as well as social studies and philosophy.

4.1.2. Grasping digitality

One of the traits of post-digitality is its intertwinement in everyday life. Nonetheless, digitality and the body have a paradoxical relationship: digitality encompasses humans, but at the same time remains invisible. Humans are often not aware of the surrounding digital systems, their characteristics, their purpose, or the assumptions built into them, nor how digitality shapes their behaviour. The contradictory nature of digitality and digital technologies is in this research defined with a somewhat paradoxical name: embodied digitality. The term refers not only to how one uses digital technologies as appendages of the body (Guillaume & Hughes, 2011; Haraway, 2013; Hayles, 2010; Stiegler, 1998), or how humans embody digital environments (Czegledy & Czegledy, 2000; Dreyfus, 1992; 2008; Hansen, 2006; Hayles, 2001; Munster, 2006), but rather how digitality is grasped and sensed in the physical world.

This dissertation proposes the term digi-grasping as a means to describe and analyse our embodied digitality: awareness and involvement in the digital world. Embodied digitality and digi-grasping are discussed in Article 3, but are

also referred to in Article 2. In general, digi-grasping could be described as active and empowered sense-making and participation in the post-digital world, where digitality is complexly coiled into physical experience. Furthermore, digi-grasping is not only based on rational understanding but also embodied understanding. Digi-grasping does not directly relate to the dualistic problem of digital and human, but more to the post-digital constant stream of data that flows through human and non-human agents, which Berry calls the 'everyday computational' (Berry, 2016). The relevance of the everyday computational comes from its emphasis on the prevalence of digitality in daily life. Digi-grasping, in turn, attempts to describe the aspects of the everyday computational or the states of being with the digital. However, the concept of digi-grasping is novel and is limited to the confines of two articles (Articles 2 and 3) in this dissertation. Furthermore, Article 2 does not directly discuss digi-grasping but defines some essential aspects of embodiment's relation to digitality through phenomenological theory. Further research could tie digi-grasping better into existing research and offer a deeper understanding of the ways digitality is embodied in everyday life.

As discussed in Articles 2 and 3, on a deeper level, embodied digitality and digi-grasping can be connected to phenomenological theories of the importance of the body. Although Heidegger does not directly discuss embodiment, his view of humans as actively bodily beings that shape our world through making is significant in phenomenology (Heidegger, 2009). Kojonkoski-Rännäli has expanded on this notion and argues that through making by hand, we craft an intentional, emphatic, and aesthetical connection to the world around us (Kojonkoski-Rännäli, 1995; 2014). In this context, digi-grasping is used to define such making, sense-making, and existing in the world which consists of both digital and physical aspects. From the context of embodied digitality, creative use of digital technologies can be seen as making by hand in the digital domain, and thus as something that shapes our knowledge of a world infused with digital technologies.

The phenomenological view of digi-grasping can be further expanded based on the idea of grasping. Merleau-Ponty defines grasping both as the knowledge that precedes rational knowledge and as one’s comprehension of the spatiality of both position and situation (Merleau-Ponty, 2012). This sense-making without rational knowing as well as the comprehension of one's position and situation are substantial in digi-grasping: through sense-making, digi-grasping defines skills that cannot be measured along the axes of the more common digital talents, such as code skills, software skills, and electronic skills. Digi-grasping can thus be used to express such knowledge of digital being that would otherwise be hard to quantify or make visible.

The concept of digi-grasping could also be further understood through DeLanda’s philosophy of synthetic reason (2012) and assemblage theory (2006, 2016). DeLanda’s work offers an intriguing way of distinguishing different concepts from social constructs to scientific simulations, as well as the ontology behind them. Concerning digi-grasping, DeLanda’s philosophy suggests that digitality, like any other assemblage, cannot be reduced to the parts that make it up. From this it follows that the sole understanding of the func-

tioning of binary code does not explain digitality as a whole. In other words, it is not necessary to account for all the parts of the whole to get a grasp of the whole, as the whole is more than the sum of its parts. Therefore digi-grasping could be such sense-making of digital assemblages that offers a way of understanding digital assemblages without necessarily understanding the technical functioning of digital technology or the structure of how algorithms gather information, or how that information is then used for or against us in different semi-autonomous feedback loops. It should be noted that, naturally, according to the same theory, creative coding is not necessary to grasp digitality, nor does this dissertation claim that: instead, creative coding can be seen as one component interacting in the digital assemblage(s). Moreover, the assemblage theory offers a way to interpret post-digital condition as a collection of dynamic properties with changing intensities. For instance, through assemblage theory, one could look at the way code, and the post-digital world is territorialized, creating possible communities and how different properties affect the intensity of the assemblage. However, to fully respect and do justice to DeLanda's philosophy much deeper introspection, research, and discussion than is possible in this dissertation would be required.

The benefit of digi-grasping lies in the theoretical discussion of the consequences or effects digital technologies have in everyday life and thus how certain aspects could be improved or discussed. Table 2 describes different modes of being with the digital and can be used to understand the degree of digi-grasping. For instance, the mode of ignorance does not directly refer to the ability to understand digital technology per se (as in being able to program or construct a computer), but to the state of awareness, one has of embodied digitality. Digi-grasping refers to the comprehending of digitality without an intellectual understanding of it, to the sensing or grasping of the surrounding post-digital world. As such, one can perhaps grasp that the projector does not display the presentation correctly because of a malfunction, without being completely aware of the exact reason. Moreover, one can grasp how code affects one's life and choose to comment or change it, without exactly understanding how the code works. Concerning creative code, digi-grasping could be seen as a useful way of discussing the awareness of the post-digital world. If we look at creative coding as embodied sense-making, of phenomenological exploration into the digital, then creative coding can be understood as a beneficial method for producing a critical understanding of the post-digital world. Creative coding also works in the different modes of being, as discussed in Article 3. From raising awareness through, for instance engaging in a drawing session with a robot, to questioning and creating through code, creative coding acts as a method for both introducing digital technology from a critical standpoint to being able to create change in and through digital technology.

MODES OF BEING IN THE DIGITAL WORLD	DESCRIPTION
Ignorance and being as given	Not being aware or questioning the relationship between the physical and digital worlds
Awareness and intentional being	Being aware of the interface between the digital and physical worlds as well as between digitality and the body
Questioning and ethical being	Problematising the relationship between the physical and digital worlds and paying attention to who defines the modes of being
Creative and aesthetic being	Transforming the digital and physical worlds based on new ethical and aesthetic understandings

Table 2. Modes of being in the digital world

4.1.3. Creative coding as a means to comprehend digitality

Even though coding is different from other craft skills by being more about intellectual, abstract making, rather than the creation of physical objects (Kojonkoski-Rännäli, 2014; 2016), coding can, in some sense, be seen as handicraft of the digital age (Cuartielles et al., 2015; Knochel & Patton, 2015; Ratto, 2011). Coding could be seen to essentially construct portions of the post-digital world, which in itself is both digital and physical.

Creative coding can be seen to widen the making-by-hand perspective by including even more of the physical world into the process through electronics, sensors, and microcontrollers, and by merging digital technologies with more traditional craft skills (Buechley & Perner-Wilson, 2012; Mellis & Buechley, 2014). Furthermore, creative coding is an art-making process, where the expression, the intent and the message become more valuable than the functionality (Greenberg, 2007; Knochel & Patton, 2015; Maeda, 2004). As such, creative coding sees digital technologies, as well as the phenomenon of digitality, as a tool or material through which one can create art. Moreover, in the post-digital age, creative coding can be seen as an essential method of observing or critiquing the contemporary world.

One possible future research strand emerges from a more embodied perspective of creative coding. As this dissertation considers code from different perspectives: code as a tool, code as a material, code as a method and code as poetic/aesthetic, these perspectives could be treated so as to broaden the understanding of how the code is embodied. Code as a tool treats coding as a means to accomplish something, as a digital extension of the body; code as a material understands code as the material to express something (creative, political, intimate); code as a method sees the act of coding as a way to comprehend and grasp the code; and code as poetic/aesthetic emphasises the aes-

thetic aspects and affiliations of code. Each of these metaphorical perspectives offers different dynamics towards the ways code is embodied. For instance, the code as a tool metaphor offers a different mesh of relationships or assemblages than, for instance, code as poetic/aesthetic does.

This research suggests creative coding being both an artistic use of code and a method for gaining an understanding of the surrounding digital world. These two modes are not separate but intertwined into each other. Through coding, one expresses oneself, but at the same time shapes the connection to the world one is creating. Such activity can be seen from the perspective of experiential art learning, as a process of conceptualising abstract concepts and integrating them into one's life (Räsänen, 2000). Furthermore, creative coding can be comprehended as a process of making by hand, where the learner constructs and comprehends their world through the act of making (Hertz, 2015; Knochel & Patton, 2015; Kojonkoski-Rännäli, 1995; Ratto, 2011). As such, creative coding can be seen as a method that uses making by hand and art in order to interpret the surrounding post-digital world. Such a view is similar to Knochel and Patton's proposition of creative coding as a 'boundary shifter' (Knochel & Patton, 2015), but further emphasises the phenomenological and art experiential perspectives of creative coding. From this point of view, creative coding can be seen as an activity or educational method that combines a varied field of themes related to digitality. Figure 3 in Section 3.4 visualises the framework of creative coding and its connection to other related themes, many of them discussed in this dissertation. As an educational method, in teaching, different factors of digitality can be brought into focus by emphasising different aspects of the creative coding process. As such, creative coding acts as a means to comprehend the post-digital world. Creative coding is further discussed in this context in Articles 2 and 4.

4.2. Practical implications

The practical implications of this thesis stem from the theoretical implications, as well as being inspired by the experiences gained during the research process. This dissertation offers two practical implications for dealing with digital technologies in education. The practices depicted here are mostly focused on art education, as well as craft education, but do pertain to education in general. Moreover, with the popularisation of phenomenon-based learning (for instance the new curriculum in Finland places an emphasis on this (Halinen, 2014)) the borders between subjects can be seen to dissolve, and large themes such as digitality, or code, could significantly benefit from the blending of, for instance, art, craft, mathematics, physics, literature, and societal subjects.

The practical implications of this dissertation can roughly be divided into two components:

1. Metaphors of code: the metaphorical view of code can help to integrate school subjects that touch on teaching programming as well as aiding in teaching programming from a broader perspective.

2. Creative coding as an educational method: creative coding can be used as an educational method in art education in order to better integrate digital

technologies into art education and give critical and empowering tools to students to allow them to deal with digitality.

4.2.1. Metaphors of code

The theoretical implications discussed in the previous section concerning the metaphors of code can be employed in a practical sense in education. First, as proposed in Article 1, the metaphorical view shows that when teaching programming in the basic curriculum, or for children in similar contexts, the aim should not only be on teaching coding as a skill, but also as a capability to better understand the world and its structures. In this dissertation's context, the focus should not only be on the functional aspects of the code, and the responsibility of teaching programming should not solely be on the shoulders of math or craft teachers, as it is now in Finland (Halinen, 2014). These perspectives should be considered when planning education and can, for instance, be used in phenomenon-based learning projects, combining several subjects around the issue of code (Halinen, 2014). Thus, teaching code can be an art and craft skill, a 'digital survival skill for digital natives', as suggested in the article, as well as a skill of logic and problem-solving.

4.2.2. Creative coding as an educational method

Similarly to the metaphors of code, the theoretical implications of creative coding can be translated into practical implications for schools. This research focused on creative coding projects mostly at the Käsityökoulu Robotti, an informal school offering weekly classes. However, projects were also executed at junior high school and universities as part of teacher education.

In general, the benefit of adding the qualifier 'creative' to 'code' as proposed in Article 4 lies in the widening of the perspective and lowering of the threshold to start to teach and learn to program. For instance, creative coding eases the framework of coding, making it easier for students, as well as reducing teachers' anxiety about 'not knowing it all'. This can help in teaching programming becoming a shared journey, in contrast to a teacher-led strict programming assignment where the teacher also has to be all-knowing. Another example is that creative coding allows for a wide range of starting points for coding, from visual play with interaction, to more critical standpoints of digitality, and further to more craft-oriented physical computing projects.

Creative coding can also be seen to benefit craft education. Coding can be regarded as a craft of the digital age (Cuartielles et al., 2015; Knochel & Patton, 2015). Creative coding can be helpful in integrating coding into craft education through the aid of creative coding platforms and tools, such as programming languages (Processing, MicroPython) and electronics platforms (Arduino, Raspberry Pi) that are widely documented and easy to use. Moreover, some of these platforms can be integrated into textiles (Lilypad, Adafruit Flora, and Gemma) and combined with traditional craft methods (Buechley & Perner-Wilson, 2012).

Moreover, the focus of this research has been on the use of creative coding in art education, and as such this dissertation puts forward the idea of creative coding as an art educational method that expands the media toolbox and vocabulary of the student (Cox, 2013; Maeda, 2004; Shiffman, 2009; The Art Club, 2017) as well as a method for what Knochel and Patton (2015) call the 'boundary shift', meaning creative coding's ability to critically assess, empower, and broaden the student's understanding of digitality as a phenomenon and digital technology as a technology.

Another perspective on creative coding in arts can be seen through the concepts of post-digitality and a new aesthetics that use the ubiquitous state of digital technologies as a given, as a landscape from which to create art (Berry et al., 2012; Berry & Dieter, 2015). Creative coding can thus be used, among more traditional means, as a means to express or critique the post-digital condition. As such, creative coding could be considered as a tool in the art educator's toolbox, a medium as valid as painting or drawing.

4.3. Limitations

This research discusses the reach and aspects of digitality in everyday life with a particular emphasis on art education. Furthermore, I use the method of creative coding to assess and understand the digitalised world. This focus leaves many other valuable pathways with little or no consideration. For instance, questions of embodiment can be researched from various other strands, including future studies (see, for example, Cubitt, 2007; Czegledy & Czegledy, 2000; Dahlin, 2012). Furthermore, the phenomenon of digitality and programming can be viewed in education from the perspectives of craft and social studies (see, for example, Berry, 2014; Buechley & Perner-Wilson, 2012; Ratto, 2011). However, the art educational model of creative coding presented here, which combines making by hand with critical assessment, action, and abstract thinking, may be beneficial in dealing with the multilayered and intertwined relation between the digital and the physical in everyday life.

One of the aims for this dissertation is to offer an empowering method to manage the problems of the post-digital era. However, the focus in this dissertation is on educational views on code, leaving out other notable perspectives. For instance, the material reality of digital technologies poses significant questions of the use of these technologies (Gabrys, 2013.; Kohtala, 2016). Furthermore, increasing digitalisation, together with advances in machine learning and robotisation, pose major economic concerns, questioning the whole economic model of contemporary society (Jungner, 2015; Koskinen & Kaivo-oja, 2016; Morozov, 2014a; 2017).

This dissertation combines many different strands of research from societal studies, philosophy, engineering, and craft to arts and art education. The diversity of research strands means that several important subjects and questions raised in these fields are left out. Furthermore, as pointed out by Knochel and Patton (2015) even though art education has investigated digitality from various perspectives, the act of coding has mainly been left without much research. As such, some perspectives in this dissertation may feel limited for fu-

ture researchers. Moreover, creative coding, or more generally using coding in education, has for the most part remained a concern for the fields of engineering, leaving many of the other strands presented here without much research. For instance, in digital humanities, the research strands established because of the effects digital technologies have on societal studies, research on code itself has only recently been taken into focus (Berry, 2016; Hayles, 2012).

The rapidly progressing nature of digital technologies pose some challenges for research. For instance, during the four years spent preparing this dissertation, some of the technologies used in creative coding have already vanished, whereas various new platforms have been introduced. The global trend of teaching programming for children has, for its part, increased the commercial competition, with many large technology firms (Apple, Microsoft, Intel) releasing and promoting their platforms for learning programming. This research has limited the technological platforms considered to only a selected few and has left out many of the newcomers. Moreover, the focus of this research is in the art and societal studies oriented aspects of code: code as an artistic medium and art and critical understanding of digitality, leaving the functional perspective with a lesser importance.

During this dissertation, I have actively been involved in the education at and functioning of the Käsityökoulu Robotti, which inevitably has had an effect on my views. The ethnographic nature of this research naturally benefits from this, but on the other side may leave some perspectives to lesser consideration. The effect may even be increased because of the lack of previous research literature on creative coding, leaving some aspects without proper critical observation. However, I have taken into account the various views and perspectives offered in the strands of societal, philosophical, and engineering studies on the code.

4.4. Avenues for further research

This dissertation is primarily focused on theory, drawing several research strands together, constructing the theoretical perspectives of creative coding as well as of using code in art education. As such, more empirical research could offer new insights into the practice of creative coding in art education, or education in general. For instance, case studies on how the art educational method could bring more broader comprehension of digital technologies and the issues raised by post-digitality could be an exciting path to take.

In the context of code literacy and empowerment in the post-digital era, machine learning along with the advances in artificial intelligence create another set of difficulties, when code can be generated within the code itself, as Berry (2017) points out. How does machine-constructed code change the structure and power relations of society or the individual? Furthermore, artistic research might offer invaluable insights into evaluating the data and code used in artificial intelligence.

In art education, research could be undertaken in integrating creative code into the art curriculum in general. This could mean the visual arts, but also arts education on a broader scale. Creative code, a multidisciplinary method,

could benefit from, and be beneficial to, art education on a more general level by bringing together distinct fields of arts, such as music, dance, and visual arts. Moreover, the idea of discussing code through metaphors, as well as the concept of digi-grasping, could be developed in the future. As an example, a metaphorical view of code could be integrated into phenomenon-based learning projects, covering issues of digitality from technicalities of code to more ephemeral subjects of code art and philosophy. As mentioned in the theoretical implications section (4.1), the code could also be examined through a new set of metaphors, presented here (code as a tool, as a material, as a method, and as poetic/aesthetic). Looking at code through these metaphors might show more clearly the embodied dynamics of code and the use of code in art education.

Last, but not in any way the least, this research has grappled with the issue of embodiment in a post-digital world. Even though many research strands have dealt with these issues in their specific domains, such as art in virtual environments (Doyle, 2015; Hansen, 2012; Munster, 2006), or, for instance, in philosophy (Dreyfus, 1992; 2008), more research in the ways art education can deal with the intertwined state of the digital and physical could be useful. Here, creative coding could be used as a method, along with the concept of digi-grasping, to evaluate and discuss the modes through which we engage with the post-digital world. Moreover, the idea of digi-grasping, in turn, could be, for example, further expanded to the materiality of the digital, covering issues of ecology and sustainability. In addition, the discussion of the relationship between the digital and physical needs to continue, and digi-grasping could be one way to broaden the discussion.

References

Ailisto, H., Collin, J., Juhanko, J., Mäntylä, M., Ruutu, S. & Seppälä, T. (eds.) (2016) Onko Suomi jäämässä alustatalouden junasta? Helsinki: Valtioneuvoston kanslia, Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 19/2016. http://tietokayttoon.fi/documents/10616/2009122/19_Onko+Suomi+j%C3%A4%C3%A4m%C3%A4ss%C3%A4+alustatalouden+junasta.pdf/5e1f46ed-415c-4763-a530-633309eafb77?version=1.0

Alano, J., Bab, D., Bell, J., Booker-Dwyer, T., DeLyser, L. A., McMunn Dooley, C., et al. (2016). *K–12 Computer Science Framework* (pp. 1–307). Retrieved from http://k12cs.org/wp-content/uploads/2016/09/K–12-Computer-Science-Framework.pdf

Alexenberg, M. L. (2011). *The Future of Art in a Postdigital Age*. Bristol: Intellect Books.

Anderson, C. (2012). *Makers: The new industrial revolution*. New York: Random House.

Arduino Music and Audio Projects. (2015). *Arduino Music and Audio Projects*. Berkeley, CA: Apress.

Assange, J., Appelbaum, J. 1., Müller-Maguhn, A., & Zimmermann, J. (2012). *Cypherpunks: Freedom and the Future of the Internet*. New York; London: OR Books.

Barbrook, R., & Cameron, A. (1996). The Californian ideology. *Science as Culture*, *6* (1), 44–72. http://doi.org/10.1080/09505439609526455

Barone, T., & Eisner, E. W. (2011). *Arts Based Research*. London: SAGE Publications.

Barrett, S. F. (2013). Third Edition. *Arduino Microcontroller Processing for Everyone 8* (4), 1–513. http://doi.org/10.2200/S00522ED1V01Y201307DCS043

Bauerlein, M. (2011). *The Digital Divide: Arguments for and Against Facebook, Google, Texting, and the Age of Social Networking*. New York: Jeremy P. Tarcher/Penguin.

Bercovici, J. (2014). Uber's Ratings Terrorize Drivers And Trick Riders. Why Not Fix Them? *Forbes,* August 14. Retrieved May 8, 2017, from https://www.forbes.com/sites/jeffbercovici/2014/08/14/what-are-we-actually-rating-when-we-rate-other-people/#6d373080ebca

Berry, D. M. (2008). *Copy, Rip, Burn. The Politics of Copyleft and Open Source*. London: Pluto Press.

Berry, D. M. (2014). *Critical Theory and the Digital*. London: A&C Black.

Berry, D. M. (2016). *The Philosophy of Software*. London: Springer. http://doi.org/10.1057/9780230306479

Berry, D. M. (2017). Prolegomenon to a Media Theory of Machine Learning: Compute-Computing and Compute-Computed. *Media Theory,* 1 (1)*: Manifestos*.

Berry, D. M., van Dartel, M., Dieter, M., Kasprzak, M., Muller, N., et al. (2012). *New Aesthetic, New Anxieties*. Rotterdam, Netherlands: V2_: Institute for Unstable Media.

Berry, D., & Dieter, M. (eds.) (2015). *Postdigital Aesthetics*.. London: Springer. http://doi.org/10.1057/9781137437204

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers and Education, 72,* 145-157. Retrieved February 9, 2014, from http://www.sciencedirect.com/science/article/pii/S0360131513003059

Bishop, C. (2012) "Digital Divide: Contemporary Art and New Media". *Artforum International*, 51 (2), 434–41.

Blikstein, P., & Krannich, D. (2013). The makers' movement and FabLabs in education: experiences, technologies, and research. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 613–616) (IDC '13), New York, New York, USA: ACM. http://doi.org/10.1145/2485760.2485884

Bogost, I. (2010). *Persuasive Games*. Cambridge: MIT Press.

Breeding, E. H. (2012). *Crafting Resistance*. (T. Wallace, Ed.). Raleigh: North Carolina State University.

Bridle, J. (2011). *The New Aesthetic*. Retrieved June 11, 2017, from http://jamesbridle.com/works/the-new-aesthetic

Buckingham, D. (2000). *After the Death of Childhood. Growing up in the Age of Electronic Media*. Cambridge: Polity Press.

Buckingham, D. (2003). Media education and the end of the critical consumer. *Harvard Educational Review, 73* (3), 309–327.

Buechley, L. (2014, October 10). *Eyeo 2014 – Leah Buechley*.) Retrieved from: https://vimeo.com/110616469.

Buechley, L., & Perner-Wilson, H. (2012). Crafting Technology: Reimagining the Processes, Materials, and Cultures of Electronics. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *19* (3), 21–21. http://doi.org/10.1145/2362364.2362369

Cangiano, S. (2016, December 14). *Coding as a way of thinking*. Retrieved July 27, 2017, from https://medium.com/progetto-grafico/coding-as-a-way-of-thinking-interview-with-casey-reas-cbb9ecdbb980

Carr, P. B. (2014, December 27). *If you still trust Tor to keep you safe, you're out of your damn mind*. Retrieved July 22, 2017, from http://pando.com/2014/12/26/if-you-still-trust-tor-to-keep-you-safe-youre-out-of-your-damn-mind/

Cascone, K. (2000). The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music. *Computer Music Journal*, *24* (4), 12–18. http://doi.org/10.1162/014892600559489

Ceruzzi, P. E. (2012). *Computing*. Cambridge: MIT Press.

Chaplin, A. D. (2005). Art and Embodiment: Biological and Phenomenological Contributions to Understanding Beauty and the Aesthetic. *contempaesthetics.org*. (3) http://contempaesthetics.org/newvolume/pages/article.php?articleID=291

Chayka, K. (2012, September 4). *Do Artists Actually Confront Our New Technological Reality?* Retrieved April 12, 2015, from https://hyperallergic.com/56319/do-artists-actually-confront-our-new-technological-reality/

Coleman, E. G. (2013). *Coding Freedom*. Princeton: Princeton University Press.

Colman, A. (2015). Net.art and Net.pedagogy: Introducing Internet Art to the Digital Art Curriculum. *Studies in Art Education*.

Conrad, D. (2014, January 5). *Writing Code As Poetry; Poetry As Code*. *Retrieved* January 1, 2017, from http://www.i-programmer.info/news/200-art/6808-writing-code-as-poetry-poetry-as-code.html
Contreras-Koterbay, S. (2016). *The New Aesthetic and Art*. Amsterdam: Institute of Network Cultures.
Cook, M. (2015). Basic Arduino. In *Arduino Music and Audio Projects* (pp. 3–30). Berkeley, CA: Apress. http://doi.org/10.1007/978-1-4842-1721-4_1
Cox, G. (2013). *Speaking Code*. MIT Press.
Cuartielles, D., Bean, J., & Rosner, D. (2015). Conversations on making. *Interactions*, *22* (1), 22–24. http://doi.org/10.1145/2685366
Cubitt, S. (2007). Media art futures. *Futures*, *39* (10), 1149–1158. http://doi.org/10.1016/j.futures.2007.05.001
Czegledy, N., & Czegledy, A. P. (2000). Digitized bodies, virtual spectacles. *Futures*, *32* (2), 103–120. http://doi.org/10.1016/S0016-3287 (99)00070-1
Dahlin, B. (2012). Our posthuman futures and education: Homo Zappiens, Cyborgs, and the New Adam. *Futures*, *44* (1), 55–63. http://doi.org/10.1016/j.futures.2011.08.007
Davies, S. (2015, July 30). Encounters with the Posthuman. *Nautilus*, 26.
de Zwart, H. (2014, December 30). *Ai Weiwei is Living in Our Future*. Retrieved August 1, 2015, from https://medium.com/@hansdezwart/ai-weiwei-is-living-in-our-future-474e5dd15e4f
Debatty, R. (2008, March 28). *Interview with Marisa Olson*. Retrieved July 22, 2017, from http://we-make-money-not-art.com/how_does_one_become_marisa/
DeLanda, M., (2001). The politics of software. *Dissent,* (Fall), 96–99.
DeLanda, M. (2006). *A New Philosophy of Society: Assemblage Theory and Social Complexity*. London: Continuum.
DeLanda, M (2012). *Philosophy and Simulation. The Emergence of Synthetic Reason*. London: Continuum.
DeLanda, M. (2016). *Assemblage Theory*. Edinburgh: Edinburgh University Press.
Deleuze, G., Guattari., F. (1998). *A Thousand Plateaus*. Tr. Brian Massumi. London: Athlone Press.
Dent, S. (2017, March 4). "*Reverse Prisma" AI turns Monet paintings into photos*. Retrieved April 12, 2017, from https://www.engadget.com/2017/04/03/reverse-prisma-ai-turns-monet-paintings-into-photos/
Denzin, N. K., & Lincoln, Y. S. (2008). S*trategies of Qualitative Inquiry*. London: SAGE Publications.
Devlin, H. (2017, April 13). *AI programs exhibit racial and gender biases, research reveals*. Retrieved April 16, 2017, from http://www.theguardian.-com/technology/2017/apr/13/ai-programs-exhibit-racist-and-sexist-biases-research-reveals
Dewey, J. (1998). *Experience and Education*. Kappa Delta Pi. New York: Touchstone
Dissanayake, E. (1992). The Core of Art. In *Homo Aestheticus: Where art comes from and why*. (1–26). Seattle: University of Washington Press.
Dougherty, D. (2012a). *Maker Market Study: An in-depth profile of makers at the forefront of hardware innovation*. Retrieved May 10, 2014, from http://cdn.makezine.com/make/ bootstrap/img/etc/Maker-Market-Study.pdf

Dougherty, D. (2012b). The Maker Movement. *Innovations: Technology, Governance, Globalization*, *7* (3), 11–14. http://doi.org/10.1162/inov_a_00135

Dredge, S. (2014, September 4). *Coding at School: A Parent's Guide to England's new computing curriculum*. Retrieved August 1, 2016, from http://www.theguardian.com/technology/2014/sep/04/coding-school-computing-children-programming

Dreyfus, H. L. (1992). *What Computers Still Can't do: A Critique of Artificial Reason*. Cambridge: MIT Press.

Dreyfus, H. L. (2008). *On the Internet*. New York: Routledge

Dreyfus, H. L., & Dreyfus, S. E. (2004). *A phenomenology of skill acquisition as the basis for a Merleau-Pontian non-representationalist cognitive science*. Berkeley: University of California Retrieved April 28, 2016 from http://ist-socrates.berkeley.edu/~hdreyfus/pdf/MerleauPontySkillCogSci.pdf.

Dwoskin, E., & Timberg, C. (2017, May 23). *Google Now Knows When its Users go to the Store and Buy Stuff*. Retrieved May 24, 2017, from https://www.washingtonpost.com/news/the-switch/wp/2017/05/23/google-now-knows-when-you-are-at-a-cash-register-and-how-much-you-are-spending/

Dyson, J. F., Forster, E. M., Fukuyama, F., Welin, S., Joy, B., Heilbroner, L. R., et al. (2009). *Technology and Society*. (G. D. Johnson & M. J. Wetmore, Eds.). Cambridge: MIT Press.

EDIT. (2017, April 5). *Hello World! – Goodbye Kuratointi*. Retrieved April 5, 2017, from http://www.editmedia.fi/nayttelyt/hello-world-goodbye-kuratointi/

Editorial. (2017, April 14). The Guardian view on computers and language: reproducing bias | Editorial. *The Guardian*. Retrieved April 16, 2017, from http://www.theguardian.com/commentisfree/2017/apr/14/the-guardian-view-on-computers-and-language-reproducing-bias

Efland, A., Freedman, K., & Stuhr, P. L. (1996). *Postmodern Art Education*. Reston: National Art Education Association.

Ellul, J. (1990). *The Technological Bluff*. Grand Rapids, Mich.: W.B. Eerdmans.

Erickson, M., & Räsänen, M. (1999). Building bridges, experiential art understanding: A work of art as a means of understanding and constructing self. *Studies in Art Education*, *40* (4), 381. http://doi.org/10.2307/1320557

Esoteric.codes. (n.d.). *esoteric.codes*. Retrieved July 28, 2017, from http://esoteric.codes

Ettinger, L. F. (1988). Art education and computing: Building a perspective. *Studies in Art Education*, *30* (1), 53. http://doi.org/10.2307/1320652

Feller, J., Anderson, R., Lessig, L., McGowan, D., OMahony, S., Kelty, C., et al. (2005). Perspectives on Free and Open Source Software. (S. A. Hissam, J. Feller, K. R. Lakhani, & B. Fitzgerald, Eds.) *Journal of Information Technology & Politics 4*, 538–99. Cambridge: MIT Press. http://doi.org/10.1080/19331680801916908

Fox, S., Ulgado, R. R., & Rosner, D. (2015). *Hacking Culture, Not Devices* (pp. 56–68). Presented at the 18th ACM Conference, New York, New York: ACM Press. http://doi.org/10.1145/2675133.2675223

Free Software Foundation (n.d.). *Free software is a matter of liberty, not price — Free Software Foundation — working together for free software*. Retrieved July 21, 2015, from http://www.fsf.org/about/

Freire, P., Freire, A. M. A. 1., & de Oliveira, W. (2016). P*edagogy of Solidarity*. New York: Routledge. http://doi.org/10.4324/9781315422817

Fuller, M., Goffey, A., Robinson, D., Pold, S., Kittler, F., Mackenzie, A., et al. (2008). *Software Studies*. (M. Fuller, Ed.). Cambridge: MIT Press.

Gabrys, J. (2013). *Digital Rubbish: A Natural History of Electronics*. Ann Arbor: University of Michigan Press. http://doi.org/10.3998/dcbooks.9380304.0001.001

Galloway, A. (2014). *Laruelle: Against the digital*. MinneaPolis:University of Minnesota Press.

Gauntlett, D. (2013). *Making is Connecting*. Hoboken: John Wiley & Sons.

Gibson, W. (1984). *Neuromancer*. New York: Ace.

Giroux, H. A. (2011). *On Critical Pedagogy*. New York:Bloomsbury Publishing USA.

Grassegger, H., & Krogeris, M. (2017, January 28). *The Data That Turned the World Upside Down*. Retrieved February 18, 2017, from https://motherboard.vice.com/en_us/article/mg9vvn/how-our-likes-helped-trump-win

Greenberg, I. (2007). *Processing*. Berkeley, CA: Apress. http://doi.org/10.1007/978-1-4302-0310-0

Groth, C. (2017). *Making Sense Through Hands*. (M. Mäkelä & P. Seitamaa-Hakkarainen, Eds.). Doctoral dissertation. Helsinki: Aalto Arts Books.

Group, T. C. A. S. W. (2014, September 5). *A Hidden Computing Curriculum?* Retrieved January 12, 2015, from http://codeactsineducation.wordpress.com/2014/09/05/hidden-computing-curriculum/

Guillaume, L., & Hughes, J. (2011). *Deleuze and the Body*. Edinburg: Edinburgh University Press.

Halinen, I. (2014, october 4). *OPS2016 Koulu katsoo tulevaisuuteen*. Paper presented at the ITK-conference, Hämeenlinna, Finland

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84* (4), 492–494. http://doi.org/10.17763/haer.84.4.b1p1352374577600

Hannula, M., Suoranta, J., Vadén, T., Griffiths, G., & Kölhi, K. (2005). *Artistic Research: Theories, Methods and Practices*. Helsinki:Academy of Fine Arts

Hansen, M. B. N. (2012). *Bodies in Code*. New York: Routledge.

Haraway, D. (2013). *Simians, Cyborgs, and Women*. New York: Routledge. Original work published 1991

Hatch, M. (2013). *The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers*. New York: McGraw Hill Professional.

Hayles, N. K. (2001). *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University of Chicago Press, 1999. Writing Machines.

Hayles, N. K. (2008). *How We Became Posthuman*. Chicago: University of Chicago Press.

Hayles, N. K. (2010). *My Mother Was a Computer*. Chicago: University of Chicago Press.

Hayles, N. K. (2012). *How We Think*. Chicago: The University of Chicago Press

Heidegger, M. (2009). *Vortrage und Aufsätze* (Pfullingen) (11th Ed.).Stuttgart: Klett-Cotta. Original work published 1952.
Heidegger, M. (2013). *The Question Concerning Technology, and Other Essays*. London: Harper Perennial Modern Classics.
Hertz, G (2015). *Conversations in Critical Making*. Vancouver, Canada: University of British Columbia; CTheory Books: www.ctheory.net/articles.aspx?id=760
Howe, D. (2015). *Surveillance Countermeasures_ Expressive Privacy via Obfuscation*. APRJA. 4(1). Retrieved from http://www.aprja.net/?p=2510
Howells, C. M. G. (2013). *Stiegler and Technics*. Edinburg: Edinburg University Press.
Husserl, E. (2013). *The Idea of Phenomenology*. Dordrecht: Springer Science & Business Media. http://doi.org/10.1007/978-94-015-7386-3
Irani, L. (2015). Hackathons and the making of entrepreneurial citizenship. *Science*, *40* (5), 799–824. http://doi.org/10.1177/0162243915578486
Jackson, M. C., & Keys, P. (1984). Towards a system of systems methodologies. *Journal of the Operational Research Society, 35* (6), 473–486. http://doi.org/10.1057/jors.1984.101
Jagodzinski, J., Garoian, C., Richardson, J., Atkinson, D., Baldacchino, J., Beier, J. L., & Wallin, J. J. (2017). *What Is Art Education?* (J. Jagodzinski, Ed.). New York: Springer. http://doi.org/10.1057/978-1-137-48127-6
Jochen P.,Valkenburg, P.M. (2006). Adolescents' internet use: Testing the "disappearing digital divide" versus the "emerging digital differentiation" approach, *Poetics*, *34* (4–5), 293-305, https://doi.org/10.1016/j.poetic.2006.05.005.
Jungner, M. (2015). *Otetaan digiloikka!* (1–28). Elinkeinoelämän keskusliitto EK. https://ek.fi/wp-content/uploads/Otetaan_digiloikka_net.pdf
Keifer-Boyd, K. T. (1996). Interfacing hypermedia and the Internet with critical inquiry in the arts: Preservice training. *Art Education*, *49* (6), 33. http://doi.org/10.2307/3193621
Kholeif, O. (2014). *You are Here. Art After the Internet*. London: Cornerhouse & SPACE.
Kiilakoski, T. (2012). *Kasvatus teknologisessa maailmassa. Tutkimus teknologisoituvasta kasvatuksesta*. Nuoristotutkimusverkoston/Nuoristotutkimusseuran julkaisuja 132. Helsinki: Nuorisotutkimusseura.
Kittler, F., Mucke, von, D., & Similon, P. L. (1987). Gramophone, Film, Typewriter. *October, 41,* 101. http://doi.org/10.2307/778332
Knobel, M, & Lankshear, C. (2007). *The New Literacies Sampler.* New York: Peter Lang.
Knochel, A. D. (2013). Assembling visuality: Social media, everyday imaging, and critical thinking in digital visual culture. *Visual Arts Research*, 39 (2), 13–27. http://doi.org/10.5406/visuartsrese.39.2.0013
Knochel, A. D. (2014). Photoshop Teaches With (out) You. *Visual Arts Research 42* (1), 71-87
Knochel, A. D., & Patton, R. M. (2015). If art education then critical digital making: Computational thinking and creative code. *Studies in Art Education, 57 (1), 21-38*.
Knuth, D. E. (2007). C*omputer Programming as an Art*. New York: ACM. http://doi.org/10.1145/1283920.1283929

Kohtala, C. (2016). *Making Sustainability:*How Fab Labs Address Environmental Issues. Doctoral Dissertation 29/2016, Aalto University. Helsinki: Aalto ARTS Books.
Kojonkoski-Rännäli, S. (1995). Ajatus käsissämme. Käsityön käsitteen merkityssisällön analyysi. Turun yliopisto, Rauman opettajankoulutuslaitos. Nide 109 / Turun Yliopiston julkaisuja. Sarja C.
Kojonkoski-Rännäli, S. (2006). Tulevaisuuden käsityötaito. *Futura* 25 (1).
Kojonkoski-Rännäli, S. (2014). *Käsin tekemisen filosofiaa*. Turku: University of Turku.
Kojonkoski-Rännäli, S. (2016, November 24). *Käsin tekeminen, digitaalinen tekeminen ja uusi tekijä-liike*. Retrieved November 25, 2016, from https://punomo-static.npn.fi/uploads/2016/11/kasin-tekeminen-digitaalinen-tekeminen_seija-kojonkoski-rannali.pdf
Kolb, D. A. (2014). *Experiential Learning: Experience as the source of learning and development*. New Jersey: FT Press.
Konopasky, A., & Sheridan, K. M. (2015, April 14). *An Experimental Study Comparing Two Educational Approaches to Making With Simple Circuits*. Educational Research Association annual meeting. Chicago, IL.
Koskinen, A., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2015). Interaction and Embodiment in Craft Teaching. *Techne Series - Research in Sloyd Education and Craft Science A*, *22* (1).
Koskinen, I. K. (2011). *Design Research Through Practice*. Amsterdam: Elsevier.
Koskinen, J., & Kaivo-oja, J. (2016, October 17). *Tulevaisuus on muutakin kuin digitaalisaatio*. Retrieved October 19, 2016, from https://vaihtoehtojensuomi.wordpress.com/2016/10/17/tulevaisuus-on-muutakin-kuin-digitaalisaatio/
Kuehn, K. (2016). Surveillance Post-Snowden. In *The Post-Snowden Era: Mass Surveillance and Privacy in New Zealand* (1st ed.). Bridget Williams Books. http://doi.org/10.7810/9780908321070_4
Kuhn, T. S. (1970). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
Kupiainen, R. (2005). *Mediakasvatuksen eetos*. Rovaniemi: Lapin Yliopisto.
Kupiainen, R., Sintonen, S., & Suoranta, R. (2008). Suomalaisen mediakasvatuksen vuosikymmenet [The decades of Finnish media education]. In R. Kupiainen, H. Kynäslahti, & M. Lehtonen (Eds.), *Näkökulmia mediakasvatukseen [Viewpoints on Media Education]*. Helsinki: Mediakasvatusseura.
Kurzweil, R. (2005). *The Singularity Is Near*. London: Penguin.
König, W., Winner, L., Hughes, P. T., Schwartz Cowan, R., Cockburn, C., Bloch, M., et al. (1985). *The Social Shaping of Technology*. (D. MacKenzie & J. Wajcman, Eds.). Open University Press. http://doi.org/10.5771/9783845269238-268
Lakoff, G. (2013). *Philosophy in the Flesh, The Embodied Mind and its Challenge to Western Thought*. New York: Basic Books.
Lakoff, G., & Johnson, M. (2008). *Metaphors We Live By*. Chicago: University of Chicago Press.
Lang, D. (2013). *Zero to Maker*. Sebastopol:Maker Media, Inc.
Lanier, J. (2010). *You Are Not a Gadget*. New York: Vintage.
Lanier, J. (2017). *Dawn of the New Everything: A Journey Through Virtual Reality*. London: Bodley Head.

Latour, B. (2014). Opening Plenary, Digital Humanities 2014 (DH2014). *Digital Humanities*. Retrieved October 5, 2014 from http://dh2014.org/videos/opening-night-bruno-latour/

Lessig, L. (1999). *Code and Other Laws of Cyberspace*. New York: Basic Books.

Lessig, L. (2009). *Code 2.0*. New York: Basic Books

Levy, S. (2010). *Hackers:Heroes of the Computer Revolution*. Sebastopol-O'Reilly Media, Inc.

Lindtner, S., & Li, D. (2012). Created in China: the makings of China's hackerspace community. *Interactions*, *19* (6), 18–22. http://doi.org/10.1145/2377783.2377789

MacMillan, T. (2012, April 30). *On State Street, "Maker" Movement Arrives*. Retrieved November 15, 2014, from http://www.newhavenindependent.org/index.php/archives/entry/make_haven/

Maeda, J. (2004). *Creative Code*. New York: Thames & Hudson. http://doi.org/10.1162/desi.2007.23.4.103

Makridakis, S. (2017). The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures*. Volume 90, 46-60, https://doi.org/10.1016/j.futures.2017.03.006.

Manovich, L. (1996, October 22). *The Death of Computer Art*. Retrieved August 6, 2017, from http://rhizome.org/community/41703/

Manovich, L. (2017). *Instagram and Contemporary Image*. Retrieved December 10, 2017 from: http://manovich.net/index.php/projects/instagram-and-contemporary-image

Knobel, M, Lankshear, C. (2007). *The New Literacies Sampler*. New York: Peter Lang

Marino, M. C. (2006). *Critical Code Studies*, http://www.electronicbookreview.com/thread/electropoetics/codology.

Martinez, S. L., & Stager, G. (2013). *Invent to Learn: Making, Tinkering, and Engineering in the Classroom*. (C. Sinclair, Ed.) (1st ed.). Torrance: Constructing Modern Knowledge Press.

McReynolds, E., Hubbard, S., Lau, T., Saraf, A., Cakmak, M., & Roesner, F. (2017). *Toys that Listen* (pp. 5197–5207). Presented at the 2017 CHI Conference, New York, New York, USA: ACM Press. http://doi.org/10.1145/3025453.3025735

Mehra, B., Merkel, C., & Bishop, A. P. (2004). The internet for empowerment of minority and marginalized users. New Media & Society, 6(6), 781-802. http://dx.doi.org/10.1177/146144804047513

Mellis, D. A., & Buechley, L. (2014). Do-it-yourself cellphones: an investigation into the possibilities and limits of high-tech diy. *32nd annual ACM conference* (pp. 1723–1732). New York, New York, USA: ACM. http://doi.org/10.1145/2556288.2557309

Mellis, D., & Buechley, L. (2012). Collaboration in open-source hardware: third-party variations on the arduino duemilanove. *The ACM 2012 Conference*, (pp. 1175–1178). http://doi.org/10.1145/2145204.2145377

Merleau-Ponty, M. (2012). *Phenomenology of Perception*. New York: Routledge. Original work published 1945.

Michel, R., Joost, G., & Mareis, C. (2014). *Design Research Now 2*. Basel: Birkhauser.

Mitchell, W. J. T., & Hansen, M. B. N. (2010). *Critical Terms for Media Studies*. Chicago: University of Chicago Press.

Moilanen, J. (2017, June 8). *3D Printing Focused Peer Production*. (T. Vadén, Ed.). Tampere: Tampere University Press.
Montfort, N., Baudoin, P., Bell, J., Bogost, I., Douglass, J., Marino, M. C., et al. (2014). *10 PRINT CHR$*. Software Studies.
Moravec, H. (1988). *Mind Children: The Future of Robot and Human Intelligence*. Cambridge, Mass.: Harvard University Press.
Moravec, H. (1997). *The Senses Have No Future, Der Sinn der Sinne International Congress* [online].Kunst und Ausstellungshalle der Bundesrepublik Deutschland, Bonn Germany.KurzweilAI.net May 15. 2001.Retrieved 20 November, 2017 from:http:// www.kurzweilai.net/articles/ art0185.html?printable=1
Morgan, G. (2006). *Images of Organization*. Thousand Oaks: SAGE Publications.
Morozov, E. (2014a). *To Save Everything, Click Here*. New York: PublicAffairs.
Morozov, E. (2014b, January 13). Hackers, Makers, and the Next Industrial Revolution. *New Yorker.* Retrieved January 29, 2014, from http:// www.newyorker.com/arts/critics/atlarge/2014/01/13/140113crat_atlarge_morozov
Morozov, E. (2015, February 1). Why cities need to fight Uber and give people a real transport choice. *The Guardian*. Retrieved May 10, 2017, from http://www.theguardian.com/commentisfree/2015/feb/01/cities-need-to-fight-uber-trasnsport-choice-evgeny-morozov
Morozov, E. (2016, December 4). Data populists must seize our information – for the benefit of us all. *The Guardian,* Retrieved February 1, 2017, from http://www.theguardian.com/commentisfree/2016/dec/04/data-populists-must-seize-information-for-benefit-of-all-evgeny-morozov
Morozov, E. (2017, July 2). To tackle Google's power, regulators have to go after its ownership of data. *The Guardian*. Retrieved July 3, 2017, from http://www.theguardian.com/technology/2017/jul/01/google-european-commission-fine-search-engines
Mumford, M. D. (2003). Where have we been, where are we going? Taking stock in creativity research. *Creativity Research Journal*, *15* (2-3), 107–120. http://doi.org/10.1080/10400419.2003.9651403
Munster, A. (2006). *Materializing New Media: Embodiment in Information Aesthetics*. Interfaces: Studies in Visual Culture, Hanover: Dartmouth College Press.
Mykkänen, J., & Liukas, L. (2014). *Koodi 2016*. Helsinki: Lönnberg Print.
Nagbot, S. (2017). *Feminist Hacking/Making*. Retrieved August 8, 2017, from http://peerproduction.net/issues/issue-8-feminism-and-unhacking-2/feminist-hackingmaking-exploring-new-gender-horizons-of-possibility/
Nash, A. (2015). An aesthetics of digital virtual environments, In Denise Doyle (ed.) *New Opportunities for Artistic Practice in Virtual Worlds*, IGI Global, Hershey, USA, pp. 1-22.
National STEM Centre. (2015). *National STEM Centre*. Retrieved January 3, 2015, from http://www.nationalstemcentre.org.uk/stem-in-context/what-is-stem
Negroponte, N. (2015). *Being Digital*. New York: Vintage. Originally published 1995.

New Left Review. (2015, February). *New Left Review – Evgeny Morozov: Socialize the Data Centres!* Retrieved April 22, 2017, from http://newleftreview.org/II/91/evgeny-morozov-socialize-the-data-centres

Noë, A. (2003). *Out of our Heads. Why you are not Your Brain, and Other Lessons from the Biology of Consciousness*. New York: Hill & Wang; 2009.

Noë, A. (2004). *Action in Perception*. Cambridge:MIT Press

Noë, A. (2015). *Strange Tools: Art and Human Nature*. New York: Hill Wang.

Nykytaiteen museo Helsinki, F. (2017). *ARS17*. Helsinki: Finnish National Gallery.

Open Source Hardware Association. (2012, May 26). *Definition (English)*. Retrieved July 20, 2017, from https://www.oshwa.org/definition/

Oshwa.org. (n.d.). oshwa.org. Retrieved July 25, 2017, from https://www.oshwa.org

Papert, S. A. (1993). *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.

Pariser, E. (2012). *The Filter Bubble*. London: Penguin UK.

Patokorpi, L. (2014). *The Art and Craft of the Machine*. Tampereen yliopisto Kieli-, käännös- ja kirjallisuustieteiden yksikkö, englantilainen filologia. Retrieved from https://tampub.uta.fi/bitstream/handle/10024/95658/GRADU-1402572504.pdf?sequence=1

Patton, M. Q. (2002). Q*ualitative Research & Evaluation Methods*. THousand Oaks: SAGE Publications.

Paul, C. (2008). *Digital Art* (Rev. and Exp. Ed.). New York: Thames & Hudson.

PBS, (2013). *The Art of Creative Coding*. Retrieved 6 March, 2016 from: http://www.pbs.org/video/-book-art-creative-coding/

Peters, B., & Coleman, G. (2016). *Digital Keywords*. (B. Peters, G. Yang, T. Gillespie, J. Steme, K. D. Harris, J. Durham Peters, et al., Eds.). Princeton: Princeton University Press.

Petzold, C. (1999). *Code: The Hidden Language of Computer Hardware and Software*. Redmond: Microsoft Press

Pollari, M. (2014, September 9). *Ohjelmointi osaksi opetusta, mistä ensiapua?* Retrieved May 1, 2015, from http://www.luma.fi/artikkelit/3183/ohjelmointi-osaksi-opetusta-mista-ensiapua

Pöllänen, S., & Kröger, T. (2004). *Näkökulmia kokonaiseen käsityöhön*. Retrieved from: http://sokl.uef.fi/verkkojulkaisut/tutkivaope/polla_kroger-.htm

Ratto, M. (2011). Critical making: Conceptual and material studies in technology and social life. *The Information Society*, *27* (4), 252–260. http://doi.org/10.1080/01972243.2011.583819.

Read, S. H. E. (1970). *Education Through Art*. (3rd Rev. Ed.). London: Faber & Faber.

Rosch, E., Thompson, E., & Varela, F. J. (1992). *The Embodied Mind*. Cambridge: MIT Press.

Rushkoff, D. (2010). *Program Or Be Programmed: Ten Commands for a Digital Age*. New York: OR Books.

Rushkoff, D. (2012, November 13). *Code Literacy: A 21st-Century Requirement*. Retrieved March 12, 2015, from http://www.edutopia.org/blog/code-literacy-21st-century-requirement-douglas-rushkoff

Rushkoff, D. (2013). *Present Shock: When everything happens now*. New York: Penguin.
Rushkoff, D. (2016). *Throwing Rocks at the Google Bus*. London: Penguin UK.
Rutsky, R. L. (1999). *High Technē: Art and Technology from the Machine Aesthetic to the Posthuman*. Minneapolis, MN: University of Minnesota Press.
Räsänen, M. (1999). Building bridges: Experiential art understanding. *International Journal of Art Design Education*, *18* (2), 195–205. http://doi.org/10.1111/1468-5949.00174
Räsänen, M. (2000). *Sillanrakentajat: kokemuksellinen taiteen ymmärtäminen*. Taideteollisen korkeakoulun julkaisu A28. Helsinki: Taidekasvatuksen osaston tutkimuksia, Taideteollinen korkeakoulu.
Saariketo, M. (2015). Reflections on the question of technology in media literacy education. In S. Kotilainen, & R. Kupiainen (Eds.), Reflections on media education futures: contributions to the Conference Media Education Futures in Tampere, Finland 2014. (pp. 51-61). Göteborg: The International Clearinghouse on Children, Youth and Media, University of Gothenburg, Nordicom. (International Clearinghouse on Children, Youth and Media. Yearbook, Vol. 2015).
Saariketo, M. (2017). Educating (critical) citizens in a digital society In J. Kiviniemi & S. Tuominen, eds., *Digital Youth Work*. Helsinki: Verke.
Sennett, R. (2008). *The Craftsman*. New Haven: Yale University Press.
Shanken, E. A. (2001). Art in the information age, *Leonardo 35* (4), 433-438.
Shiffman, D. (2009, September 23). I*nterview with Casey Reas and Ben Fry.* Retrieved July 10, 2017, from http://rhizome.org/editorial/2009/sep/23/interview-with-casey-reas-and-ben-fry/
Sirkin, D., Martelaro, N., & Ju, W. (2017). Make This! Introduction to Electronics Prototyping Using Arduino. *CHI Extended Abstracts*, 1224–1227. http://doi.org/10.1145/3027063.3027094
Sonvilla-Weiss, S. (2010). Introduction: Mashups, remix practices and the recombination of existing digital content. In *Mashup Cultures* (pp. 8–23). Vienna: Springer, Vienna. http://doi.org/10.1007/978-3-7091-0096-7_1
Source Code Poetry 2016. (2016). *Source Code Poetry 2016*. Retrieved January 1, 2017, from http://sourcecodepoetry.com/
Söderberg, J. (2015). *Hacking Capitalism: The Free and Open Source Software Movement*. London: Routledge.
Stallman, R. M. (2014). *Reasons not to use Uber.* Retrieved May 8, 2017, from https://stallman.org/uber.html
Stallman, R. M. (2015, March). *Free Hardware and Free Hardware Designs*. Retrieved July 18, 2017, from https://www.gnu.org/philosophy/free-hardware-designs.en.html
Stallman, R. M., Gay, J., & Lessig, L. (2002). *Free Software, Free Society*. Boston: Free Software Foundation
Steam Not Stem. (2010). *Steam Not Stem*. Retrieved March 21, 2014, from http://steam-notstem.com/
Steiner, C. (2013). *Automate This: How Algorithms Took Over Our Markets, Our Jobs, and the World*. New York: Portfolio/Penguin
STELARC Hamburg City. (1999). Parasite visions: Alternate, intimate and involuntary experiences. *Body & Society*, *5* (2-3), 117–127. http://doi.org/10.1177/1357034X99005002007

STEM to STEAM. (2016). *STEM to STEAM*. Retrieved May 10, 2016, from http://stemtosteam.org/

Sterling, L. (2015, May 20). *An Education for the 21st Century Means Teaching Coding in Schools*. Retrieved July 1, 2015, from http://theconversation.com/an-education-for-the-21st-century-means-teaching-coding-in-schools-42046

Sternberg, R. J., & Sternberg, K. (2011). *Cognitive Psychology*. (6th Ed.). Belmont: Wadsworth Publishing

Stiegler, B. (1998). *Technics and Time: The Fault of Epimetheus*. Palo Alto: Stanford University Press.

Sweeny, R. W. (2010). *Inter/actions/inter/sections: Art Education in a Digital Visual Culture*. Reston, VA: National Art Education Association.

Taidekiikari (2017, April 2). *Ars17 - pää täyteen digi(h)älyä*. Retrieved April 5, 2017, from http://www.taidekiikari.net/index.html/2017/04/01/ars17-paa-tayteen-digihalya/

Taylor, G. D. (2014). *When the Machine Made Art: The Troubled History of Computer Art*. New York: Bloomsbury Publishing USA. http://doi.org/10.5040/9781628929980

Taylor, P. G. (2000). Madonna and hypertext: Liberatory learning in art education. *Studies in Art Education*, *41* (4), 376. http://doi.org/10.2307/1320680

Taylor, P. G., & Carpenter, B. S., II. (2015). Inventively linking: Teaching and learning with computer hypertext. *Art Education,* 55(4), 6-11

The Art Club. (2017). *Casey Reas*. Retrieved July 22, 2017, from https://zine.electricobjects.com/interviews/casey-reas

The Finnish Association of Art Schools for Children and Young People. (2013). *Basic Education in the Arts in Finland*. Retrieved from: http://whm13.louhi.net/~youngart/wp-content/uploads/2013/09/Basic-Education-in-the-Arts.pdf

Tinworth, A. (2012, January 15). *What is Post Digital?* NEXT Conference. Retrieved July 22, 2017, from https://nextconf.eu/2012/01/what-is-post-digital/

Tochetti, S. (2012). DIY biologists as "makers" of personal biologies: How MAKE Magazine and Maker Faires contribute in constituting biology as a personal technology. *Journal of Peer Production,* 2. Available at: http://peerproduction.net/ issues/issue-2/peer-reviewed-papers/diybiologists-as-makers/

Toikkanen, T. (2015, November 26). *Coding in School: Finland Takes Lead in Europe - Learning Environments Research Group*. Retrieved December 3, 2015, from http://legroup.aalto.fi/2015/11/coding-in-school-finland-takes-lead-in-europe/

Turkle, S. (2005). *The Second Self: computers and the human spirit*. Cambridge: MIT Press.

Turkle, S. (2011). *Alone Together. Why We Expect More from Technology and Less from Each Other.* New York: Basic Books, Inc.

Turkle, S. (2015, September 26). *Stop Googling. Let's Talk*. Retrieved September 30, 2015, from http://www.nytimes.com/2015/09/27/opinion/sunday/stop-googling-lets-talk.html

Uricchio, W. (2011). The algorithmic turn: Photosynth, augmented reality and the changing implications of the image. *Visual Studies*, *26* (1), 25–35. http://doi.org/10.1080/1472586x.2011.548486

Vaden, T. (2005). Digital nominalism. Notes on the ethics of information society in view of the ontology of the digital. *Ethics and Information Technology*, *6* (4), 223–231. http://doi.org/10.1007/s10676-005-0350-7
Vallance, C. (2015, July 22). *Car Hack Uses Digital-radio Broadcasts to Seize Control*. Retrieved September 10, 2015, from http://www.bbc.co.uk/news/technology-33622298
van Boeckel, J. (2013). *At the Heart of Art and Earth*. Aalto University publication series DOCTORAL DISSERTATIONS, 73/2013 Helsinki: Aalto ARTS Books
Välimäki, M. (2005). *The Rise of Open Source Licensing: A Challenge to the use of Intellectual Property in the Software Industry*. Helsinki: Helsinki University of Technology.
Veeber, E., Syrjäläinen, E., & Lind, E. (2015). A discussion of the necessity of craft education in the 21st century. *Techne Series – Research in Sloyd Education and Craft Science A*, *22* (1).
Vierkant, A. (2010). *The Image Object Post-Internet*. Jst Chillin. http://jstchillin.org/artie/ vierkant.html
Wajcman, J. (2014). *Pressed for Time: The Acceleration of Life in Digital Capitalism*. Chicago: University of Chicago Press.
Weiner, L. R. (1993). *Digital Woes: Why we should not depend on software*. Boston: Addison-Wesley
White House (2014). *President Obama Expands "Educate to Innovate" Campaign for Excellence in Science, Technology, Engineering, and Mathematics (STEM) Education*. Retrieved March 10, 2016, from http://www.whitehouse.gov/node/7578
Williamson, B. (2015). Political computational thinking. *Critical Policy Studies*, 1–20. http://doi.org/10.1080/19460171.2015.1052003
Williamson, B. (2016). Silicon startup schools: Technocracy, algorithmic imaginaries and venture philanthropy in corporate education reform. *Critical Studies in Education*, Vol. 0, Iss. 0, 1–19. http://doi.org/10.1080/17508487.2016.1186710
Wing, J. M. (2006). Computational thinking. *Communications of the ACM*. March 2006/Vol. 49, No. 3. 33-35.
Wired Staff. (1998, January 12). *Negroponte*. Retrieved July 21, 2017, from https://www.wired.com/1998/12/negroponte-55/
Wolf, L. (2009). *Digital Art*. Langenscheidt: h.f. ullmann.

Publication 1

Dufva, T. & Dufva, M.. Metaphors of code—Structuring and broadening the discussion on teaching children to code. Thinking Skills and Creativity , 22, 97–110. DOI: 10.1016/j.tsc.2016.09.004, 2016

Thinking Skills and Creativity 22 (2016) 97–110

Contents lists available at ScienceDirect

Thinking Skills and Creativity

journal homepage: http://www.elsevier.com/locate/tsc

Metaphors of code—Structuring and broadening the discussion on teaching children to code

Tomi Dufva [a,*], Mikko Dufva [b]

[a] Aalto-University, School of Arts, Design and Architecture, Finland
[b] VTT Technical Research Centre of Finland Ltd, Tekniikankatu 1, Tampere, P.O. Box 1300, 33101 Tampere, Finland

ARTICLE INFO

Article history:
Received 29 December 2015
Received in revised form 22 August 2016
Accepted 7 September 2016
Available online 15 September 2016

Keywords:
Code
Code literacy
Metaphors
Education
Programming
Teaching programming
Pedagogy
Media literacy

ABSTRACT

Digital technology has become embedded into our daily lives. Code is at the heart of this technology. The way code is perceived influences the way our everyday interaction with digital technologies is perceived: is it an objective exchange of ones and zeros, or a value-laden power struggle between white male programmers and those who think they are users, when they are, in fact, the product being sold. Understanding the nature of code thus enables the imagination and exploration of the present state and alternative future developments of digital technologies. A wider imagination is especially important for developing basic education so that it provides the capabilities for coping with these developments. Currently, the discussion has been mainly on the technical details of code. We study how to broaden this narrow view in order to support the design of more comprehensive and future-proof education around code and coding. We approach the concept of code through nine different metaphors from the existing literature on systems thinking and organisational studies. The metaphors we use are machine, organism, brain, flux and transformation, culture, political system, psychic prison, instrument of domination and carnival. We describe their epistemological backgrounds and give examples of how code is perceived through each of them. We then use the metaphors in order to suggest different complementary ways that ICT could be taught in schools. The metaphors illustrate different contexts and help to interpret the discussions related to developments in digital technologies such as free software movement, democratization of information and internet of things. They also help to identify the dominant views and the tensions between the views. We propose that the systematic use of metaphors described in this paper would be a useful tool for broadening and structuring the dialogue about teaching children to code.

1. Introduction

Digitality as a phenomenon defines our era. Digital technologies have secured their place in business and in social relations as well as in culture. Digital technologies affect society, but often these changes are taken as given, without broader discussion on the impacts and consequences (König et al., 1985). This is troubling, because digital technology functions in various positions in our society. For example, a high percentage of stock trading is done through trading algorithms with little human involvement. (Washington, 2015; Steiner, 2013). Modern cars carry so much digital technology they have been called "computers on wheels" (Foley Lardner LLP, 2014; Hirsch, 2015). Social media, essentially a digital phenomenon, has defined

* Corresponding author.
E-mail addresses: tomi.dufva@aalto.fi (T. Dufva), mikko.dufva@vtt.fi (M. Dufva).

http://dx.doi.org/10.1016/j.tsc.2016.09.004

new ways of interaction and has influenced culture. There is also evidence that digital technologies shape the way people think, by supporting, sharing and expanding people's cognitive processes(Barzilai and Zohar, 2006). By digital technologies, we mean technologies that are based on digital signal processing, which can be reduced to a flow of ones and zeroes, and which usually utilize information networks to function.Digital technologies allowed for the rampant innovation and growth that started around the 1940s and are defined as the digital age (Ceruzzi, 2012). Digital technologies include all the technologies from smartphones and computers to automated manufacturing and decentralized communication protocols. Digitalization presents new challenges, that, in essence, call for an understanding of digital technologies. The so-called digital divide, that formerly implied the distinction between those who have access to the internet and to those who do not (Mehra, Merkel, & Bishop, 2004) can now be seen as the divide between those who understand digital technologies and those who do not. (For a historical view on ICT in education, see Wilson, Scalise, & Gochyyev, 2015). Mark Warschauer points out that, in today's society, the ability to access, adapt and create knowledge using information and communication technologies is critical to social inclusion (Warschauer, 2004).

The access to digital resources, as well as the ease of use of those resources, has increased, but the understanding of the code has not kept the same pace. This can be seen, for example, within the digital natives discussion. Knowing how to use a tablet computer at the age of two does not mean that one understands the way the machine works or the code behind it. It does not even imply that one could learn to cope with the technology (Kupiainen, 2013). This can also be seen from Carita Kiili's dissertation (Kiili, 2012) where she states that many young adults have problems assessing and evaluating search results in the net. In essence, digital technologies are a source of inequality, which is problematic given their ubiquity in modern society.

Code is the heart of every digital technology and substantially shapes its behaviour. In this paper, we define code as a digital language with a set of assumptions about the users and the world. Code is used to create programs that control digital technologies, from automated factories to personal computers, and from connected home appliances to services providing social networking. Thus, code, in our working definition, refers to the principles and choices made, and is not restricted to any specific programming language. Coding is the act of writing code and building programs, which includes making implicit and explicit choices about the purpose, framing and scope of the program.

The key motivation for this paper is that, because digital technologies are always programmed and are thus based on code, understanding code and the assumptions inherent in it is necessary for full participation in modern society. The code in digital technologies is not value-free, rather it widely reflects both conscious and subliminal values of the programmer, a software company or society's understanding of good code. Digital technology's operating models are not immutable laws of nature, but rather flexible models that are designed and controlled by humans (Lessig, 1999, 2009). Code does not reflect objective truth about the world. Instead, it constructs laws in the digital realm. Without understanding how these laws are formed, we are not able to fully participate in the discourse of our digital life (Giroux, 2011; Lessig, 2009, Rushkoff, 2010). Technology does not impinge upon us from the outside of society, but interweaves into our society in the same way as the political or economic system does, and is also dependent on these other systems, which can alter the way, or speed, of technological progress (König et al., 1985). Without including technology as a coherent part of societal discussion the effects of technology and its relations to other systems stay ambiguous. Furthermore discussion around the ramifications of technologies are crucial as technology has the tendency to convert social, scientific, governmental and human problems into technical problems (Williamson, 2015).

We propose code literacy as a way to participate to the discussion around the effects of digital technologies on society. Code literacy does not directly allude to learning to program in the traditional sense, rather it implies the understanding of the code and its intentions and context. The notion of literacy illustrates the case: In the same way that not all literate individuals become authors, not all code-literate individuals become developers. Still, literate people have the necessary skills and the apprehension of reading and writing.

Understanding code does not emerge naturally from lived experience, but has to be taught. The code used to form the present digital world, be it an operating system, software or stock- trading algorithm, is distinctly different from the everyday analogue tools, such as hammer, pen or paintbrush, used to form the material world. One example of this is the binary system of two alternate states, often represented as 1 and 0. Code is binary and, therefore, can be reduced to "yes or no" decisions. However, as Rushkoff argues, human lives are not binary and thus trying to represent them using these binary systems is problematic (Rushkoff, 2010).

Learning to code and digital learning systems are deeply intertwined in political, societal and commercial structures (Williamson, 2015, 2016). We argue that current teaching about digital technologies, programming and code and the discussion around it does not take fully into account the societal and ethical dimensions of code. Thus, our goal in this paper is to broaden the discussion and propose a structure for understanding different views on code. To facilitate this, we describe nine metaphors of code based on four paradigms. Through the use of metaphors and their associated paradigms we wish to support a larger and more holistic view on code and digital technologies.

This paper is structured as follows. After this introduction, in Section 2 we describe nine general metaphors that cover four common paradigms of social theory as well as different assumptions about the complexity of the world and the relations between stakeholders. In Section 3, we apply these metaphors to structuring the discussion around code and illustrating various viewpoints expressed about what code is and how it influences society. In Section 4, we focus specifically on education around code and coding, and suggest different views on teaching code. Section 5 concludes the paper.

		Assumptions about the values and interests of stakeholders		
		Unitary	Pluralist	Coercive
Assumptions about the nature of the world	Simple	Machine Organism	Culture Political system	Psychic prison Instrument of domination
	Complex	Brain Flux and transformation		Carnival

Fig. 1. Nine metaphors categorised by their assumption of the complexity of the context or "system", and the values and interests of stakeholders (Jackson, 2003).

2. Metaphors for structuring the discussion around code

The language around concepts such as technology has been analysed before through methods such as discourse analysis and critical discourse analysis (Fairclough, 1995; Weiss and Wodak, 2006). Our analysis is based on this stream of qualitative analysis of the concepts used to describe a phenomenon. However, in this paper we use metaphors as the tool for analysing and structuring the discussion. Metaphors are a mechanism for describing, understanding and comparing abstract concepts, and can be defined as mappings across conceptual domains (Lakoff, 2009). Through a metaphor, the entities in one domain are mapped onto entities in another domain. For example, a segment of code could be mapped to represent an organ in the human body. Metaphors can be powerful in influencing how an issue is approached or a problem is framed, but we are mostly unaware of their effect (Thibodeau and Boroditsky, 2011).

Metaphors have been used in a systematic fashion in management and organisational studies (Jackson, 2007; Morgan, 2006). We use the metaphors introduced by Morgan (Morgan, 2006) and developed further by Jackson (Jackson and Keys, 1984). These nine metaphors describe different views on the concept of code and include the metaphors of machine, organism, brain, flux and transformation, culture, political system, psychic prison, instrument of domination and carnival. The nine metaphors are based on four common research approaches or paradigms in social theory: the functionalist, interpretive, emancipatory and postmodern (Jackson and Keys, 1984; Jackson, 2007) based on (Louis, Burrell, & Morgan, 1983) and (Alvesson and Deetz, 1996).

Paradigm, in its original sense, means the set of ideas, assumptions and beliefs that shape and guide the scientific activity of a research community (Kuhn, 1970). The aim in the functionalist paradigm is to demonstrate law-like relations between objects. The emphasis is on function and efficiency. The functionalist paradigm is based on the assumption that an understanding can be gained through scientific method and empirical research. The interpretive paradigm, as the name suggests, is more interested in the interpretations people make of different issues and situations. These interpretations guide people's behaviour. Thus, the aim is to understand these interpretations and the underlying culture through methods such as hermeneutics and ethnography. The emancipatory paradigm focuses on the power relations in society. It is aimed at "emancipating", i.e. liberating and empowering people and unmasking domination through ideological and cultural critique. The postmodern paradigm is opposed to all three former paradigms, which it views as modernist. It critiques the attempt to form grand narratives and assuming rationality and direction. Its methods include deconstruction and genealogy.

The metaphors can be structured along two dimensions (Jackson, 2003). The first considers the assumptions made about the world. The world can be seen as relative simple, meaning that the key issues are knowable, causal relations between the issues are straightforward and known, and goals are achievable by following a detailed plan. On the other hand, the world can be seen to be a complex, interconnected "mess", where there are many surprises, unintended consequences, non-linear causal relations and, thus, the focus is more on adapting and "muddling through" than following a plan.

The second dimension covers three different perceptions of the values and interests of the stakeholders: unitary, pluralist and coercive. Stakeholder values and opinions can be assumed to be unitary, meaning that the stakeholders tend to agree on a common goal and share a similar worldview. A pluralist view criticises this as too simplistic, and assumes that there are multiple, competing goals and worldviews. A coercive view goes further and frames the stakeholder relations as a power struggle between those in power and those who are oppressed. Thus, there are multiple goals and worldviews, but not all are given voice.

The metaphors can be positioned to a matrix using these two dimensions. (Fig. 1, see also the system of system methodologies by Jackson & Keys (1984) (Jackson, 2003). While Jackson (2003) uses metaphors to describe organisations, we argue that they can be used also to shed light on more general issues. We will next briefly describe the metaphors and then, in Section 3, use them to illustrate various views of code.

The first four metaphors are based on the functionalist paradigm and view the values and interests of stakeholders, i.e. people who are influenced by code, as unitary and thus not problematic. The machine metaphor depicts issues as linear, mechanistic sequences from inputs to outputs and emphasises efficiency above all. The organism metaphor describes a

Table 1
Nine metaphors for understanding the nature and purpose of code.

Metaphor	Description of code	Purpose of code	Example
Machine	Code is a linear sequence of commands that is input to a machine	To control a machine	Algorithms, code listings
Organism	Code is a set of objects that represent different parts of a program	To create functionality, to interact	Object-oriented programming
Brain	Code is the intelligence of man-made systems	To create new information, to learn	Cloud computing, artificial intelligence
Flux and transformation	Code is the process that creates changes in man-made systems	To create change, to create structure	Software as life changer
Culture	Code is a way of thinking and understanding the world	To connect and create a community	Free software foundation, Hacker ethcis, Hacker Culture
Political system	Code is a statement and a tool to shape the world	To establish a new form of society	Code as political construct. Internet
Psychic prison	Code is a system which requires people to adapt to it	To shape people	Filter bubble
Instrument of domination	Code is a tool for domination	To control people	Data as a source of power
Carnival	Code is a tool for art and creativity	To challenge existing mindsets, to open up discussion	Creative coding.

non-linear interaction between different parts and highlights the functional differences and roles of the parts. The brain metaphor, stemming from cybernetics, puts emphasis on learning and adaptation in a hierarchical system, while the flux and transformation focuses on the processes and logics of change.

The culture and political system metaphors are based on the interpretive paradigm, which puts emphasis on the different interpretations that exist of an issue. The culture metaphor focuses on values, beliefs and worldviews, and thus highlights the community or communities around the issue. The political system metaphor also emphasises values and worldviews, but focuses more on the governance and decision-making around the issue. It thus highlights relevant institutions and political structures.

The psychic prison and instrument of domination metaphors are based on the emancipatory paradigm. Similar to the interpretive paradigm, the assumption is that there are multiple differing worldviews, beliefs and values. However, now the focus is on the power relations between the worldviews and on bringing ignored or suppressed aspects and questions to the surface. The psychic prison metaphor focuses on the structures, both intentional and unintentional, that suppress individual freedom and learning. The instrument of domination metaphor focuses more on the group level and highlights how the issue is used as a way to control others.

The final metaphor, carnival, is based on the postmodern paradigm, which seeks to question the way the issues are discussed and framed in general by deconstructing the main concepts. The carnival metaphor thus highlights the creative and chaotic side of an issue, in order to use the issue itself to question the way it is discussed. This may often result in a multi-faceted picture of the issue, which is not as coherent as in the other metaphors.

Our purpose in describing and applying these metaphors is not to argue that one is better than the other, or that a certain view to an issue should be followed. Rather, our purpose is to use the metaphors to structure the discussion around code. The nine different views help to understand the discussions and decisions around code. In addition to giving a more comprehensive view of what code is, the different metaphors also highlight what is missing from the discussions and which views conflict with each other. We will return to these questions in the discussion section, after we have applied the nine metaphors in the next section.

3. Understanding code through metaphors

In this chapter, we propose ways to define code through the different metaphors. We illustrate how code is defined and how it appears in the different metaphors. In Table 1, we provide a summary of these descriptions of code, views of the purpose of code as well as some examples. These results are elaborated below.

3.1. Functionalist paradigm

The functionalist paradigm introduces a mechanical and unitary view of code. It focuses on the straightforward advancement of code as a technical invention. Inside the paradigm, four different metaphors present different nuances. As a whole, the functionalist paradigm can be marked as a dominant view: It predominantly acts as a common and shared understanding of the meaning of code.

3.1.1. Machine: code as a mechanistic, linear sequence of commands

The machine metaphor represents the fundamental mechanical comprehension of code. Code is seen as a sequential set of instructions that are input into and processed by a machine: the computer. The results are then displayed to the user. In other words, the user expects that the computer as a machine will deliver her or him results based on a set of instructions – the code.

From a technical perspective, the machine metaphor demonstrates the fundamental physics of code. Paul E. Ceruzzi calls this the digital paradigm – that all code, computation and control are done in binary form. With binary form, he not only refers to a binary arithmetic – the number system that uses just two symbols, 1 and 0–but also to the use of binary logic that is used to control, encode and transmit the information (Ceruzzi, 2012). In essence, all digital information is based on the binary code.

In the machine metaphor, computers, the machines that are able to process digital information, are basically input and output machines. They take instructions, process those instructions and output information based on the instructions. Code represents the set of instructions in the languages that the computers can understand. Computer languages vary from lower level languages to higher level languages. Lower level languages are closer to the binary logic that computers use on the implementation level, while more complex, higher level languages are easier for humans to write and read. Whatever the language is, in the end all of these languages are compiled back to a binary form.

From the machine-metaphor view, the higher level languages can be seen as rational progression towards getting the intended process completed faster and easier. Even though the code in higher level languages is farther from the binary code, being closer to the language humans use increases efficiency through a manageable working environment and less friction in the process. Many modern compilers are generally more efficient in compacting the code to binary than are humans, resulting in a more robust code (Ceruzzi, 2012). Machine metaphor illustrates the straightforward process of digital technology – progress means creating ever more efficient machines to interpret increasingly complex code.

The machine metaphor represents a reductionist viewpoint and a hierarchical way of processing data. Tasks are broken into parts and processed in a strict order governed by the rules of the program – the code. This assumes that the context is simple and can be reduced to separate parts, and that a single common goal exists. Seeing code only through this metaphor results in an emphasis on the process without questioning the direction, which, furthermore, often results in advocacy of a single way of coding without embracing possible diversity of goals and processes.

In the context of planning education, this could mean a debate on which coding language should be taught, but not questioning what the purpose of teaching the coding language is in the first place. The underlying rationale behind such a debate is that coding is a skill for the job market and teaching coding – the right language and style – is thus good for ensuring the employability of future workforce.

3.1.2. Organism: code as a combination of objects

The organism metaphor sees the code as a construct of many individual parts that work together. This can be seen as a continuation of the machine metaphor, as it focuses further on increasing the efficiency of code by further breaking the code into more manageable parts, thus allowing programmers easier ways to reaching their goals (Petzold, 1999). The organism metaphor represents another common mechanical view of the code. It can also give us an idea of how modern code is created and how software problems are addressed – code is not seen as a simple set of instructions but as a structured sets of code, organs, that together create a working program, or a body.

On a technical level, the organism metaphor corresponds to object-oriented programming (Cox, 1985). Object oriented programming breaks the linear set of instructions to different objects that can be addressed when necessary. Most modern programming languages favour this approach as it allows for a more structured management of complex code that makes problem solving easier, thus increasing efficiency (Petzold, 1999).

Furthermore, the organism metaphor represents a structural approach, which allows the creation of more flexible code that can interact simultaneously to multiple inputs and outputs. Coding is still seen as a mechanic practice of giving instructions, but the linearity of the instructions is broken into interconnected parts. Object-oriented thinking and problem solving are at the heart of modern coding. Many commonly used higher level programming languages incorporate object-oriented thinking. As such, object-oriented thinking and problem solving break the traditional narrative and sequential ways of thinking and understanding (Manovich, 1999).

3.1.3. Brain: code is intelligence

In the brain, metaphor code is not only sets of organized instructions, but represents the intelligence of computers. Code is seen as the man-made brain: intelligence that not only structures information, but also creates and modifies it. Code is the central unit that processes and develops information in the system, be it software, computer or any other machine.

One example of seeing code through the brain metaphor is the notion of artificial intelligence. Artificial Intelligence (AI) is the study of how to build or program computers to enable them to do what minds can do (Boden, 1996). The idea of artificial intelligence has captivated many past and present thinkers long before digital technologies existed (McCorduck, 2004). Modern programmable computers can be seen as the manifestation of the idea of artificial intelligence – before computers, machines were built for a specific task and purpose (Ceruzzi, 2012). The idea of a general device, the purpose of which could be changed indefinitely by programming, was revolutionary. A similar idea of programming and reprogramming fuels the current developments in artificial intelligence – pattern recognition, computational learning theory and machine learning

stem from the idea that the code inside the computer can change, or, loaning a biological term, it can evolve (Chrisley and Begeer, 2000). The ultimate extreme in artificial intelligence is technological singularity in which artificial intelligence has progressed beyond human intelligence and becomes sentient through code (Kurzweil, 2005; Lanier, 2010). Through the brain metaphor, this development is seen as natural and desirable; the metaphor contains no problematization or critique. Code only actualizes the potential and predetermined ultimate goal of digitality. In technological singularity, code truly becomes the brains of the computer.

The brain metaphor is naturally not limited to the discussion of artificial intelligence. We can also look at other systems of code through the brain metaphor. It extends the functionalist paradigm further, from lists and objects to a system with a central controller who has the authority to control and modify the code. A good example is cloud computing, where the machines running the code become secondary. Even though the code is running on physical computers, the physical location is irrelevant. Code is seen to escape the hardware and have a life of its own in the cloud of digital computing power. In a similar way, modern digital voice-controlled assistants aim to create the illusion of an omniscient virtual entity and can thus be seen to represent code in its abstract form. They seem to exist beyond the machinery running them.

3.1.4. Flux and transformation: code will save the world

The Flux & Transformation metaphor is similar to the brain metaphor, as it also concentrates on the development of the code, but, rather than framing code as the intelligence of machines, it sees code as a transformative tool to continually change the world. It therefore broadens the focus from computers and code to their environment. It can bring into focus the aspiration many software companies share, at least in their public declarations, which is not just to create better products, but to make the world a better place. From Google's "Do no evil"-slogan to Facebook's CEO Mark Zuckerberg, who argues that his company's mission is to "make the world more open and connected" (Mark Zuckerberg, Sarah Lacy Interview Video, 2008), software companies are focusing on solving problems rather than creating products. As Jeff Jarvis has said, "Complexity is a solvable problem in the right hands" (Jarvis, 2012).

Code is seen as a medium that is both flexible and can be deployed rapidly and widely. It only takes one person and a few nights to come up with a solution that has the possibility to change or disrupt the way we see the world. The Flux and Transformation metaphor thus moves the focus from the advancement of efficient code to code's ability to advance our lives. The metaphor is firmly grounded in the functionalist paradigm, and focuses on how to create a change rather than on the question of why change is needed, what the direction should be and who gets to decide the direction. Thus, it does not problematize the act of making the world a better place. The problems are seen as simple, straightforward tasks that can be solved with code.

3.2. Interpretive paradigm

Whereas the functional paradigm and the last four metaphors saw the code as a fairly straightforward issue that mainly concerns technical aspects and implementations, the interpretive paradigm has greater interest in the different ways of seeing and understanding code. In contrast to the unitary perspective of functionalism, the interpretive paradigm takes into account the plurality of stakeholder values and opinions in the context in which the code is created and deployed.

3.2.1. Culture: code creating communities

The Culture metaphor focuses on the communal aspects of code, for example on what kind of communities and subcultures are formed around code and coding, and what kinds of values are projected to code. The popularisation of digital technology has led to a whole industry that has created its ways of working and communicating as well as its ethical rules, which are reflected in the way code is perceived and treated. The culture is not unambiguous; rather it consists of many sub-cultures and ideologies.

The Culture metaphor brings into focus the ways code affects how the surrounding environment – the world – is interpreted. One example of this is the free software movement. The movement has a long creation history dating back to the early phases of computers. Before personal computers, computers were mainly used in corporations, universities and research laboratories. Most of the operating systems were open. Anyone could read and modify the way operating systems worked. When the industry began to grow, especially into businesses and households, and the operating systems evolved, many manufacturers started closing their code, thus preventing collaboration and modification. For some, this development went against their basic rights and values as programmers. On this basis, Richard Stallman, then working for the Artificial Intelligence Lab at MIT (Stallman, Gay, & Lessig, 2009), created the GNU project (Fsf, 2015a), on which Linus Torvalds later built his free operating system, Linux. A few years after starting the GNU project, Stallman founded the Free Software Foundation (FSF) (Fsf, 2015b).

These projects can be seen as a wish to maintain the academic ethos and collaboration as well as the hacker culture alive in the developer culture (Stallman et al., 2009). The stated goal for these projects is societal change. FSF wants to change the way we use, distribute and think about code. At the core of FSF are four rights that, according to FSF, are essential in keeping the development and use of code democratic:

> The freedom to run the program as you wish, for any purpose (freedom 0).

> The freedom to study how the program works, and change it, so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.
>
> The freedom to redistribute copies so you can help your neighbor (freedom 2).
>
> The freedom to distribute copies of your modified versions to others (freedom 3). By doing this, you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this (Fsf, 2015a).

These rights align with hacker culture, which, at the time Stallman founded the foundation had different connotations than the word "hacker" has now. Hacker was a positive concept rather than depicting a coder with a criminal aptitude. Hacker culture believes in free access, freedom of information, and improvement to the quality of life (by using digital technologies) (Levy, 2010). Even though the aims of FSF are political and ideological, it also reveals the richness in the developer culture, with its core beliefs, tradition and ethics. As Coleman (2012) says in her book Coding Freedom, The ethics and aesthetics of hacking (Gillen, 2013), there is a common pride and joy in offering your "handmade" code to others, as well as the genuine interest in learning from other developers' code.

As the examples above illustrate, inspecting coding from the perspective of the cultural metaphor reveals the rich and many-sided culture of code and reveals that coders sit simultaneously at the centre and at the margins of the liberal tradition (Gillen, 2013). Code both creates many sub-cultures and at the same time affects the general culture. Thus, code and coding is not only about giving instructions to a machine or solving problems, but also about influencing the culture.

3.2.2. Political system: code structuring the society

The other metaphor in the interpretive paradigm, political system, offers a somewhat different view from the culture metaphor. Whereas the culture metaphor sees the world from the individual and grassroots perspective, the political system metaphor takes a look at how code creates hierarchical systems that affect our everyday lives. Besides influencing its culture, code also affects society in a more systematic manner. The way our coded environments are built, as well as the way code itself is built, constructs the ways we act in the world. From operating systems and programs to protocols that hold the constructions together, the many ways we interact in the world are channelled through the code. *"Code is law"*, as Harvard lawyer and author of Code and other laws of cyberspace (Lessig, 1999, 2009) Lawrence Lessig puts it. In the political system, metaphor code is seen as not mere mechanical technology, but a malleable force that can be changed by the culture that developers live in, as well through governmental or any other institutional control. One example of this is the internet, as it offers us a multi-faceted view of how political systems affect the way code is structured. Born out of research projects in the US defence department, the internet spread to universities and from there to the public. In the beginning, the internet was seen as a revolutionary medium that allowed every participant to not only receive, but to send information (Lessig, 2009), thus enabling a 'real' democratic process. The internet was seen as free by its nature, offering equal opportunities to everyone (Fleischer et al., 2014, Lessig, 2009). A quote from MIT professor Dave Clark's 1992 speech at the IETF (Internet Engineering Task Force) conference depicts the ethos well: "*We reject: kings, presidents, and voting. We e believe in: rough consensus and running code.*" (Borsook, 1995) But as Lessig wrote already in 1999, The internet has no nature per se, but is dependent on our choices:

> 'We can build, or architect, or code cyberspace to protect values that we believe are fundamental, or we can build, or architect or code cyberspace to allow those to disappear. . . . . .There is no choice that does not include some kind of building. Code is never found; it is only ever made, and only ever made by us' (Lessig, 1999).

Sixteen years later, the structure of the internet has been changed considerably through the actions of several different sources. When Lessig was writing the first revision of the Code and other laws of cyberspace, the current topic was free mp3-downloads and the music industry's reaction to it, leading to digital rights management (DRM) and legislation. At about the same time, China was waking up to the threats that the internet, as a source of non- controlled information might impose to its governance, causing it to erect the "Great Firewall of China", a project that aims to manage all the net communication in and out of China (University of California-Davis, 2007). And a few years ago Edward Snowden revealed the widespread internet surveillance that governments were engaged in, thus displaying yet another layer of the internet and what has been made possible through code. As Mikael Brunila proposes, the internet has enabled panspectric control, which alludes to the way information can be gathered from the internet. In traditional panoptic control, information is gathered from the suspects after they actually become suspects; in panspectric control, everything is collected, all the time, and from everyone (Fleischer et al., 2014).

These kind of structural changes in societal architecture give us a glimpse of the reach code has. The internet is a multi-layered construction of code, which is inherently intertwined with political systems. Code is not free from these ties, but rather has a decisive role in creating the architectures we use every day. The questions of how to control code, who can control code and why would we control it are increasingly more relevant in our lives, as code permeates more and more of our everyday activities via the internet-based services, but also through increasingly "smart" gadgets.

3.3. Emancipatory paradigm

Many of the issues that arise in the interpretive paradigm can also be seen as issues in the emancipatory paradigm, and vice versa. The difference comes from the focus on power relations. In the interpretive paradigm, there are differing views on the purpose and goals related to code, but the differences between these views are assumed to be somewhat unproblematic. We can examine the different views that code offers to culture and politics. In contrast, the metaphors in the emancipatory paradigm focus more on what the power relationship is between these various views, and how these power relations are reflected or enacted through code. For example, does code enable or restrict emancipation both at the individual and societal level?

3.3.1. Psychic prison: code restricting human behaviour

The psychic prison metaphor takes a look at the power relations from the individual perspective. It brings into focus the code that underlies technological inventions from the emancipatory perspective. Is a code good for an individual? Does this code help an individual accomplish the things she wants to do? How does the architecture of code influence the life of an individual? One example of this is what Eli Pariser calls the filter bubble (Pariser, 2012), meaning the possible outcome that may result from using invisible automatic personalisation algorithms. The algorithms are invisible in the sense that an individual does not choose to use them, nor sees them. Rather, she has opted into them automatically when using certain services. One example Pariser gives is the difference in results people get by doing the same Google search. Using the same search words yields different results, based on dozens of different signals Google collects from the user. (Pariser, 2012) A quote from Mark Zuckerberg, CEO of Facebook illustrates the idea further:

> "A squirrel dying in your front yard may be more relevant to your interests right now than people dying in Africa."

As Parisier says

> "Your filter bubble is your own personal, unique universe of information that you live in online. And what's in your filter bubble depends on who you are, and it depends on what you do. But the thing is that you don't decide what gets in. And more importantly, you don't actually see what gets edited out. "

The idea of the filter bubble shows the possible problems caused by code that is selecting content from the internet unbeknown to the user. Having no control over this code creates an unequal situation between the user and the code. On what basis does the code select what content is shown and what is hidden? What are the bases of the code selecting the showable content? And what are the motivations of the developer who decided these rules embedded in the code? Are the rules decided with the user's assumed benefit in mind, or are they defined to benefit the business that the developer is in?

On a more abstract level, the psychic prison metaphor also focuses on the issue of how we might knowingly or unconsciously change ourselves because of code. For example, MIT professor Sherry Turkle talks about the ways we require digital devices to actualize our feelings. She gives an example of her study where she concluded that some teenagers require the passing of text messages to truly justify and experience their feelings, like falling in love or being scared (Turkle, 2011). Another point Turkle, along with many others such as Jaron Lanier (Lanier, 2010) and Douglas Rushkoff (Rushkoff, 2010, 2013) bring up, is the alienation that code allows us to feel. Turkle speaks about the feeling of "alone together" where we are physically in one place with other people, but mentally somewhere else (Turkle, 2011). Another example of this abstract level is obsessive gaming. How does the code in the games take into account the player and their needs? Is the code made in a responsible way or does it use tricks to hook the player into spending more time or money on the game?

The psychic prison metaphor highlights how the power relationship between individual and code is problematic. The ways code changes us may not always be for the good. As Jaron Lanier asks, do coded environments change people, or do people change themselves because of them? Lanier's point is that, in order to use, enjoy or respect code, humans can adjust to many levels of intelligence. Sometimes, code requires us to be less intelligent than we really are (Lanier, 2010). Self-control is required in order to break free from the psychic prison. Both Lanier and Turkle use the term dieting. In a similar vein, Parisier is concerned that the filter bubble might feed us too much of the information we enjoy and too little of the information we need, and uses the term "information junk food" (Pariser, 2012). Turkle asks for a digital diet: a reflective and introspective review of what and how we want to use our devices (Turkle, 2011). The psychic prison metaphor enables the exploration of the ways code might limit or shape the current and future potential of humans.

3.3.2. Instrument of domination: knowledge and control of code is power

The instrument of domination metaphor focuses on the power relations between societal and communal constructs and code. Code is seen as a force that is used intentionally in order to shape and control others. The metaphor concentrates on those aspects of code that may enable some group to dominate another group in ways that might not have been possible or feasible before. In other words, does the architecture of code have an aptitude to cause inequality? If that is the case, then those who understand and have access to code have more power than those that do not. Because of the widespread nature of code, these issues are not just marginal questions. Code is not just at the heart of computer screens or smart phones, but affects a wide variety of things from pacemakers to cars and manufacturing units, offering unforeseen access to the everyday lives of humans.

For example, if computer browsers can transfer so much information to Google that it can confidently personalise our search results, how much more does the mobile phone with its sensors and location data add to this information? Or, what about our payment data collected from credit card purchases and ewallets and the increasing popularisation of the internet of things? If all the data from house temperature and the efficiency of a person' habits of recycling to their history of payments are funnelled to one or a few institutions or corporations, does it not create the possibilities for domination? In a similar way, the invisibility of code in the filter bubble creates problematic situations, as does the invisible and closed collection of data to both individuals and to society as a whole (Morozov, 2013). Collection of data is problematic because of the lack of democratic availability of the data. Most of the information collection is done by large tech companies that keep the information to themselves or only sell it to other businesses (Fleischer et al., 2014).

The problematics of domination are not just limited between tech companies and users, but the relationship can be seen in several different scenarios. When more devices get both transformed into code and connected to networks, new opportunities arise for misuse. For example, modern cars can be thought to be computer servers on wheels (Vallance, 2015), and when they get connected to outside networks they can also be hacked and remotely controlled, as two new studies demonstrate (Checkoway et al., 2015; Vallance, 2015). Being able to take almost full control of any network-connected car from the comfort of your sofa, using just your computer and mobile phone exemplifies the significance of domination by code very well.

Other more well-known examples are the privacy breaches that Edward Snowden revealed. The widespread nature of how governments spy on citizens illustrates the reach that digital devices and code have in our lives. Without acknowledgment, we are giving up information about our lives that we did not even know about before. One important angle on the massive data collection is that it is impossible to collect or manage that amount of information without code, thus increasing the dependency we have on code. The increase is not just in the pure processing power, but even more in the capabilities of evaluation of the information. Also, this processing power is more reachable by those that have more assets and time, creating an imbalance that is further increased by the lock-in effects, common in digital technologies (Lanier, 2010) (Morozov, 2013) (Rushkoff, 2010). The imbalance is further increased by the prevalent proprietary nature of the code (Stallman et al., 2009; Vaden, 2005).

Yet, even if code allows for new kinds of domination, and may be biased towards those who have more assets, it does also enable rebelling against those currently in power. The construction of code allows for clever individuals to use it for their own purposes. For example, hackers in China or in the Arab world during the Arab spring or in other countries that suppress freedom of speech can benefit from code architecture by tunnelling messages securely to the outside world, passing governmental restriction and walls. In the instrument of domination metaphor, code can be seen as architecture that allows more multi-layered ways of domination, and is both the instrument and the product of power relations.

3.4. Postmodern paradigm

Functionalist, interpretive and emancipatory paradigms provide different views of what code is. The postmodern paradigm provides a "meta-view" and focuses on the mechanisms through which we create these views. Essential questions in this paradigm are how do we see code, what influences our perception of code and what other ways could there be? The emphasis is thus on deconstructing the process of giving meaning to what code is.

3.4.1. Carnival: understanding of code can be created through creative use of code

To illustrate how the concept of code can be approached in the postmodern paradigm, we employ the metaphor of a carnival. In the carnival metaphor, many perceptions can exist at the same time and playfulness, suspension of disbelief and multi-facetedness is embraced. The carnival metaphor focuses on the creative and artistic sides of code. It illustrates how code can inspire people and evoke various emotions. It also helps to explore the different reactions people have expressed towards code. However, the carnival metaphor does not fully reflect all the aspects of the postmodern paradigm and the endeavour to deconstruct the meaning and sense of code. Art and creativity can be seen as ways of deconstruction but they are not the only ways to do this, nor can we say that they are only views into the multiple nature of postmodern. Jackson (2007) uses also the metaphor of broken mirror to reflect the change from one solid picture into various differenting pictures of the whole. A good example of the understanding of code in the carnival metaphor is creative coding, which concentrates on the expressive rather than functional sides of code. Creative coding has its origins in the 1960s, when artists first began to experiment with computers. In recent decades, creative coding has seen an upheaval along with several tools aimed at the creative professionals.

> "Creative code may sound like an oxymoron, but as in many technical processes in the art studio, creativity may emerge once rules are learned and then broken (Knochel & Patton, 2015)."

Creative coding allows artists to question and critique code and, at the same time, express themselves through code. In a similar way that a brush or a pen is a tool for visual artist, code can be seen and used as an artistic instrument. Code, like any instrument has its own biases and ways of working, creating a medium that allows things to be expressed in unique ways. As Cox says in his book Speaking Code: "Code, like language in general, evokes complex processes by which multiple voices can be expressed, modified, and further developed" (Cox, 2013, p.6)

One example of creative coding is "Smile TV", a project by David Hedberg. "Smile TV" is a simple TV-set, but it only works when the viewer is smiling, thus creating a real working product using modern technologies and at the same time critiquing digital culture (Scholz, 2014). The works in creative code are diverse, where some focus on the visual effects or on visualisation of data, such as Jer Thorp's works (Thorp, 2009). And some use digital technologies to reveal hidden layers in these techniques, such as the Immaterials project that materialises the existence of GPS-signals (Arnall, 2014) and Wifi signals (Arnall, 2011).

As the examples indicate, creative coding comments on the views of code expressed within multiple paradigms and metaphors. Whereas some works can take a functionalist angle and use code in an almost similar way when developing "working" software, some may misuse and break the workings of code altogether. And still others may use code as a way to critique the power issues arising from the code. As such, the world around creative code is ambiguous and multi-faceted.

Creative coding illustrates how the carnival metaphor incorporates various views captured in other metaphors, joins them together and deconstructs them. Like many art works, the carnival metaphor focuses more on the experience than the theory. The art created does not justify its presence, but rather waits to be experienced. As such, it can show us those sides of code that may not be otherwise understood, or seen.

In this section, we have described different perceptions of code through the use of nine metaphors. In order to illustrate how these metaphors can be used to structure and inform a topical issue, we apply them to the ongoing discussion about teaching programming in schools.

4. Applying the metaphors of code to developing education around code and coding

Teaching programming has lately been a much discussed subject in education. Finland along with many countries, such as Estonia, the UK and the US have started or are starting to incorporate programming in the basic curriculum in schools (Halinen, 2014; Sterling, 2015). Our research is mainly focused on the discussion, decisions and development of teaching programming in Finland, although it can be seen to echo similar tendencies in other countries such as UK (For example see Williamson, 2015). When the teaching of programming moves from the level of higher education to the level of basic education, the understanding of programming becomes increasingly important: does the basic curriculum just prepare younger students for the digital industry as a possible workforce, or does it offer educational views on the complex issues around widespread digital technology? This problematic is cumulative, as teachers are often unclear of the intended aims and goals of teaching programming (Pollari, 2014). The discussion around code is often limited to methods of teaching programming, such as different platforms etc., and to which programming language would be best in programming. In some cases, code is also seen as part of art and craft, such as in Finland, where teaching programming is going to be divided between maths and craft lessons (Opetushallitus, 2014).

In general, the views around teaching code are fairly limited and mechanical. Even though critique towards technological determinism has been expressed, the idea that technology acts as independent and often objective force is still often taken as granted. (König et al., 1985). Understanding the way code structures our daily interaction with machines and how it mediates our interaction with fellow humans (through digital services) is rarely seen as an essential societal skill. Rather, the code underlying the interfaces and services we use is taken as given. This limits students' capability to identify and question the implicit assumptions about this code. From the stance of critical pedagogy, Paulo Freire asked even in the 1990s to find a policy on teaching technology (Freire, Freire, & De Oliveira, 2014). He acknowledged the increasing speed that technologies advance and how this creates life changes, and asks for "*the quality of getting or creating ability to answer to different challenges with the same speed that things change. This is one of the demands of contemporary education. We need to form and not to train.*" (Freire et al., 2014).

In the previous section we applied nine metaphors to illustrate different perceptions of code and highlight various issues related to these perceptions. We now apply these metaphors to structure and broaden the discussion around teaching programming at the level of basic education. The most prevalent question that arises from applying the metaphors is about the objectivity of code and programming. Is code seen as an objective exchange of ones and zeroes, or is it a value-laden power struggle between white male programmers and those who think they are users when they are, in fact, the product being sold?

The current dominant discussion emphasises more the objective, logical and mathematical sides of code as described by the functionalist paradigm and especially by machine and organism metaphors. Code is seen as an unproblematic language to be taught in order for the students to have a more secure employment. In the context of planning education, this could mean a debate on which coding language should be taught, but not questioning what the purpose of teaching the coding language is in the first place. The underlying rationale behind such a debate is that coding is a skill for the job market and teaching coding – the right language and style – is thus good for ensuring the employability of future workforce. The endeavour to improve education on learning to code can be seen as a large campaign where both political and economical actors lobby their interest through boundary organisations (Williamson, 2015).[1]

[1] Williamson's research is focused on the "learning to code" endeavour in the UK, but there are similarities with the developments taken towards including coding to the basic curriculum in Finland (Saariketo, 2015).

But if we assume that the world around us is more complex, this perception of code does not hold. The brain and the flux & transformation metaphors move the focus from the mechanical viewpoint and put emphasis on the intelligence of code. Code is not a simple language to be learned in order to ensure employment, but rather a complex man-made tool for shaping the world. In other words, code is seen as an instrument that creates and changes our everyday behaviour and practices. Artificial intelligence, as well as the solutionist attitude of many software firms, show the possibilities and reach code has. Code is everywhere in our lives. From this standpoint, merely choosing a programming language to be taught or creating basic logical understanding might not be enough.

When learning and teaching code is understood more broadly, code can be more easily connected to real life situations. Thus students can have a more direct experience of the implications of the code. This can enable discussion in the classroom about the role of code in our society – a crucial discussion but one where there are no right answers. Here Freire's idea of forming rather than training students becomes more clear. Freire sees that education has the responsibility to create digital minds. Training students to learn a programming language is not enough, as it does not form the students to understand the full reach of digital technologies, thus preventing them from creating knowledge themselves, i.e. possessing a critical mind (Freire et al., 2014).

The ubiquitous nature of code leads to the question of whether we agree on how good or beneficial code is today? And furthermore, what do we mean by good or beneficial? These questions are essentially intertwined with public education's aims to help students not only to live in society but to understand societal structures and ethics, and also to question them. The interpretive paradigm focuses on these questions and the way code influences society and culture. The culture metaphor affixes code to its cultural context, offering views on the different mindsets, ideologies and trends that influence the code. The culture metaphor explains the societal, cultural and subcultural contexts that affect the ways code is written, offering us ways to better experience the reasons why code exists the way it does. For example, understanding the ways free software, open source software and proprietary software differ from each other can offer ways to impact software development as well as to offer an understanding of the design choices in the software. Furthermore, the cultural metaphor can offer views of the historical context of code and digital technologies. Understanding the beginning of digitality, such as Babbage's machine, Leibniz's binary logic, or Ada Lovelace, the first computer programmer, might offer valuable connections that increase the student's personal understanding of code.

The metaphor of political system approaches much of the same area as the culture metaphor, but more from the societal standpoint. It addresses critical questions of the purposes and morals of code: What part does code play in the democratic system? The political system metaphor offers ways to approach subjects such as privacy, whistle-blowers, free software ideology or the structure and politics of the internet. It can also be expanded to the philosophies and history of technological invention, and to a discussion about technological determinism.Possible questions to be raised in this metaphor include how technology changes society, what are the relations between technology and society and does society or other aspects of society, such as political decisions or economical forces shape the way the code we use today is made? Ars Industrialis manifestos by French philosopher Bernard Stiegler might offer interesting starting points for classroom discussions about the role of code in society as they contrast technology's role starkly as *pharmacon:* both the drug and remedy (Stiegler, 2005, 2010). The metaphor of code as a political system also offers more reflective viewpoints on the future of code, which might offer interesting talking points when contrasted with brain or flux and transformation metaphors.

The interpretive paradigm emphasises the various perceptions about the background and the context for the code we use every day. This information can be beneficial for teachers as well as students to increase their understanding of the reach that code has. It can offer practical discussions on the reasons and implications of the software we use every day. It also offers the idea that code is not a fixed thing, but a malleable invention, which is affected by the coders, the culture around it as well as societal decisions and politics. This kind of critical understanding might be what Freire calls forming instead of training.

The emancipatory paradigm further increases the humanistic viewpoints on the code. Code is seen not only as mechanical or societal, but as a force that has the power to affect and influence our lives. It questions the intentions of the code as well as our position in the coded world: Do people have the power to decide, or are they being manipulated? Is code made to be truly helpful for users, or is it created for the benefit of the coder or the company? The psychic prison metaphor considers these questions from the individual standpoint and the instrument of domination metaphor deals with the power struggle from a broader context.

The psychic prison metaphor asks how people (students, teachers, parents) are influenced by the code and what are its ramifications. Do the coded environments change people, and if so, how? Or, as Jaron Lanier asks, Do we change ourselves because of them? (Lanier, 2010). How does the filter bubble affect learning or searching for information? How different can the coded environments be, for example, between teacher and students? How do we deal with the loss of common "neutral" media such as newspapers? Themes like obsessive gaming, social media usage, and critical, self-aware ways of using digital technologies are at the heart of this metaphor. These questions can also lead to self-discovery in the digital age through different challenges students can face, for example being without a smartphone for a day or projects such as the Bored and Brilliant project organised by the WNYC radio show Note to self (http://www.wnyc.org/series/bored-and-brilliant/). Wajcman has written about the paradox of loss of time when using digital technologies that save us time in more detail in her latest book (Wajcman, 2014).

While the culture and political system metaphors dealt with many cultural and societal issues from a general standpoint, the instrument of domination metaphor emphasises the power issues of the code. Code is a tool for building structures

Table 2
Different views to teaching code.

Metaphor	Meaning for education on code and programming.
Mechanic	Learning a programming language, or logic.
Organism	Understanding the structure of complex code.
Brain	Understanding the "intelligence" of code.
Flux & Transformation	How code can solve problems.
Culture	Placing coding in its cultural context.
Political System	Understanding the ways code affect society.
Psychic Prison	Understanding how code influences individual.
Instrument of domination	Seeing the power issues involved in code.
Carnival	Learning to use code as a way of self-expression and as a tool of understanding code.

and obtaining knowledge, and whoever has control over these structures and information has power over the users of the software or service. As Rushkoff points out, some of the issues created by code are inherent in the code itself, and some are created by the people developing code. An example of the former is the binary nature of the code that leads to a different mode of thinking that humans do. An example of the latter is the hijacking of the social connections that people form over the internet, meaning that the platforms that offer connections use those connections for their own purposes, such as harvesting data for market purposes, etc. (Rushkoff, 2010). Being aware of the power issues inherent in the code is crucial in forming a critical understanding of the code. Increased awareness of these issues and their origins on the level of code may help students to become more critical consumers, and it may also trigger changes in these platforms. When the students are able to detect controlling structures inherent in code, they are also empowered to challenge these structures, which may create a new power dynamic in the digital world.

The former examples have been mostly about gaining skills (learning a programming language), learning how the world works (the ubiquity and influence of code) and debating what is preferable. The postmodern paradigm and the carnival metaphor highlight the creativity, emotions and experience in education about code. The postmodern paradigm emphasises the deconstruction and reconstruction of the concept of code. The carnival metaphor uses the code itself to challenge the idea of the code. It can encompass all the other metaphors or views of code to create a statement of itself. The tool it uses for this is the code itself. It shows how important arts and craft is in the understanding of the code. Not only can creativity be used to invent something, but it can also be used as a tool to understand code, or to critique code and its usage. Creating something by hand is an important tool in knowledge acquirement (Kojonkoski-Rännäli, 1998), and creative use of the code could be argued to be part of the craft skills of 21st century.

The different viewpoints and suggestions for education around code and programming are summarised in Table 2. Our point is not to recommend that a particular metaphor should be followed and others ignored, or to suggest a ranking of the usefulness of the metaphors. Instead, we argue that all of the areas metaphors brings out should be included in the teaching of code and programming. As we proposed in the beginning it might be more fruitful to think about teaching programming in the basic curriculum to be more about improving code literacy, than about teaching coding as merely a mechanical skill. Code literacy includes both understanding the more ambiguous and multiplexed issues that exist around code, and the basic principles and logic of coding. The machine and organism metaphors in the functionalist paradigm set the basis for understanding code from the technical perspective. This helps to understand how code is used in more complex real world situations, as the brain and flux & transformation metaphors illustrated. The culture and political system metaphors help to broaden the scope towards societal issues, while the instrument of domination and psychic prison metaphors illustrate the coercive characteristics code can have. Finally, the postmodern paradigm and the carnival metaphor broaden the method of learning about code from thinking and discussing to experience and creativity.

These metaphors may be implemented in several ways as a part of ICT education. The metaphors and the issues may be divided between different disciplines and may thus be more evenly distributed in existing school subjects. Or they can be studied as a whole in a phenomenon-based learning project, which can combine different school subjects together to form a larger picture of the subject. Or programming could be its own subject, where it would not only include mechanical knowledge of programming, but it would incorporate all

the different issues we have brought forth in this article. Code could also be seen as a new subject: as a "digital survival skills for digital natives." In Finland, recent plans to focus more on phenomenon-based learning discloses many interesting opportunities in teaching code and creating a broader understanding around it – improving code literacy. (Halinen, 2014).

5. Discussion & conclusion

As coding and code literacy are gaining more popularity, what is meant by code becomes more important. However, the societal discussion around code is still fragmented and partly superficial, focusing only on a few points of view and more often on a mechanical understanding of the code. There is also traction between these different views. Our article illustrates ways of embracing the tensions, and also of raising the neglected aspects to the educational agenda. We propose that the aim should not be just on code and programming as a skill (coding), but also as a capability of better understanding the world and its structures. This understanding can be seen to become even more important in the future.

We propose the metaphors as a useful heuristic for illustrating different viewpoints on code. However, some limitations can also be identified. From the theoretical side, the key question is do the metaphors adapted from the organisation and systems science cover every important aspects of the code? This relates to another limitation, that of the lack of empirical evidence. While we do illustrate the metaphors with examples, we have not presented an empirical case study where all the metaphors would be used. We believe that such a case study would be a fruitful direction for further research and would help to refine the metaphors Furthermore an empirical case study would enable analyzing how different metaphors interact with each other, where are the main tensions, which metaphors are closely linked to each other etc. Further research could also focus on the social practices and historical backgrounds of these metaphors. These points are out of the scope of this article, as we have focused on describing the metaphors and using them as a lens to focus on various effects code has. Another strand of possible future research might be the focus on emancipatory paradigm and for example dissecting platform monopolies and the ways they govern the code. Related to this, interesting work regarding educational platforms has been done by Williamson. (For example see: https://codeactsineducation.wordpress.com).

Our approach illustrates that there are multiple views of what code is and how it influences our everyday lives. This understanding may help to better reflect the needs of future education. The metaphors we have described can be used as one way to support the planning of education around coding as well as to structure the discussion around code and coding. From a societal standpoint, the metaphors help to identify the dominant metaphor and thus to understand the current direction of code-based issues. Contrasting the dominant metaphor with the alternative views proposed by the metaphors presents us with alternative future directions. However, we do not propose that any singular view is sufficient by itself. Rather, the focus should be on opening the discussion, allowing plural views and helping to take different views systematically into account.

Acknowledgements

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement no 293446 – Platform Value Now: Value capturing in the fast emerging platform ecosystems.

References

Alvesson, M., & Deetz, S. A. (1996). Critical theory and postmodernism approaches to organizational studies. In *The SAGE handbook of organization studies*. pp. 255–283. SAGE Publications Ltd. http://dx.doi.org/10.4135/9781848608030.n8
Arnall, T. (2011). *Immaterials*,. Retrieved August 1, 2015, from. http://www.nearfield.org/2011/02/wifi-light-painting
Arnall, T. (2014). *Immaterials*,. Retrieved August 1, 2015, from. http://www.nearfield.org/2014/08/satellite-lamps
Barzilai, S., & Zohar, A. (2006). How does information technology shape thinking? *Thinking Skills and Creativity*, *1*(November (2)), 130–145. http://dx.doi.org/10.1016/j.tsc.2006.08.001
Boden, M. A. (1996). *Artificial intelligence*. Academic Press.
Borsook, P. (1995). How anarchy works. *Wired*,. Retrieved 1.8.2015 from:. http://www.wired.com/1995/10/ietf/
Ceruzzi, P. E. (2012). *Computing*. MIT Press.
Checkoway, S., McCoy, D., Kantor, B., Anderson, D., Shacham, H., Savage, S., et al. (2015). *Comprehensive experimental analyses of automotive attack surfaces*. Center for Automotive Embedded Systems Security. http://www.autosec.org/pubs/cars-usenixsec2011.pdf
Chrisley, R., & Begeer, S. (2000). *Artificial intelligence*. Taylor & Francis.
Coleman, E. G. (2012). *Coding freedom – The ethics and aesthetics of hacking*. USA: Princeton University Press.
Cox, B. J. (1985). *Object oriented programming*. Addison-Wesley.
Cox, G. (2013). *Speaking code*. MIT Press.
Fairclough, N. (1995). *Critical discourse analysis*. Longman Group Limited.
Fleischer, R., Kullenberg, C., Brunila, M., Nikkanen, H., Purokuru, P., Wåg, M., et al. (2014). Verkko suljettu. In M. Brunila, & K. Kallio (Eds.),. Into Kustannus.
Foley Lardner LLP. (2014). Is it a car or a computer on wheels? *Dashboard Insights*,. Retrieved: 1.8.2015. From. http://www.autoindustrylawblog.com/2014/06/09/is-it-a-car-or-a-computer-on-wheels/
Freire, P., Freire, A., & De Oliveira, W. F. (2014). *Pedagogy of solidarity*. Left Coast Press Inc.
Fsf. http://www.fsf.org/about/
Fsf. https://www.gnu.org/philosophy/free-sw.html
Giroux, H. A. (2011). *On critical pedagogy*. USA: Bloomsbury Publishing.
Halinen, I. (2014). Presentation: Ops2016-koulu katsoo tulevaisuuteen. *ITK-conference*, 10.4.2014.
Hirsch, J. (2015). *Elon Musk: Model S not a car but a sophisticated computer on wheels*. (March 19 Retrieved September 20, 2015, from]. http://www.latimes.com/business/autos/la- fi-hy-musk-computer-on-wheels-20150319-story.html
Jackson, M. C., & Keys, P. (1984). Towards a system of systems methodologies. *Journal of the Operational Research Society*, *35*(6), 473–486. http://dx.doi.org/10.1057/jors.1984.101
Jackson, M. C. (2003). *Systems thinking*. SAGE Publications Ltd. http://dx.doi.org/10.4135/9781446263556
Jackson, M. (2007). *Systems approaches to management*. Springer Science & Business Media.
Jarvis, J. (2012). *Rewired youth?, BuzzMachine*. Retrieved July 1, 2015. from:. buzzmachine.com/2012/02/29/rewired-youth/
König, W., Winner, L., Hughes, T. P., Schwartz, R. C., Cockburn, C., Bloch, M., et al. (1985). The social shaping of technology. In D. MacKenzie, & J. Wajcman (Eds.),. Open Univeristy Press. http://dx.doi.org/10.5771/9783845269238-268
Kiili, C. (2012). *Online reading as an individual and social practice*. Jyväskylä Studies in Education.
Knochel, A. D., & Patton, R. M. (2015). If art education then critical digital making: Computational thinking and creative code. *Studies in Art Education*.
Kojonkoski-Rännäli, S. (1998). *Ajatus Käsissämme*. University of Turku, Rauman opettajankoulutuslaito.
Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
Kupiainen, R. (2013). *Diginatiivit Ja Käyttäjälähtöinen Kulttuuri*. Widescreen.fi. Retrieved April 16 2015 From:. http://widerscreen.fi/numerot/2013-1/diginatiivit/
Kurzweil, R. (2005). *The singularity is near*. Penguin.
Lakoff, G. (2009). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 202–251). Cambridge: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781139173865.013
Lanier, J. (2010). *You are not a Gadget*. Vintage.

Lessig, L. (1999). *Code and other laws of cyberspace*. Basic Books (AZ).
Lessig, L. (2009). *Code 2.0*. CreateSpace.
Levy, S. (2010). *Hackers*. O'Reilly Media, Inc.
Louis, M. R., Burrell, G., & Morgan, G. (1983). Sociological paradigms and organizational analysis. *Administrative Science Quarterly*, *28*(1), 153. http://dx.doi.org/10.2307/2392394
Manovich, L. (1999). Database as symbolic form. *Convergence: The International Journal of Research Into New Media Technologies*, *5*(2), 80–99. http://dx.doi.org/10.1177/135485659900500206
McCorduck, P. (2004). *Machines who think: A personal inquiry into the history and prospects of artificial intelligence*. Natick, Mass: AK Peters.
Mehra, B., Merkel, C., & Bishop, A. P. (2004). The internet for empowerment of minority and marginalized users. *New Media & Society*.
Morgan, G. (2006). *Images of organization*. SAGE Publications.
Morozov, E., 2013. To Save Everything. Click Here: The Folly of Technological Solutionism. PublicAffairs.
O'Neill, N. (2008). *Mark Zuckerberg, Sarah Lacy interview video*. Retrieved August 8, 2015. From:. adweek.com/socialtimes/mark-zuckerberg-sarah-lacy-interview- video/304287
Opetushallitus. (2014). *Perusopetuksen opetussuunnitelman perusteet*.. Retrieved July 21, 2015 From:. http://www.opinsys.fi/ohjelmointi-ja-perusopetuksen-opetussuunnitelman-perusteet
Pariser, E. (2012). *The filter bubble* (ibooks ed.). UK: Penguin.
Petzold, C. (1999). *Code: The hidden language of computer hardware and software* (1st ed.). Redmond: Microsoft Press.
Pollari, M. (2014). *Ohjelmointi Osaksi Opetusta, Mistä Ensiapua?* Luma.fi Retrieved September 9, 2014. From:. http://www.luma.fi/artikkelit/3183/ohjelmointi-osaksi-opetusta-mista-ensiapua
Rushkoff, D. (2010). *Program or Be programmed*. OR Books.
Rushkoff, D. (2013). *Present shock: When everything happens now*. Penguin.
Saariketo, M., 2015. Presentation: Koodauksesta kansalaistaito? Koodaustaidon julkinen määrittely yhteiskunnallisena kamppailuna at Toimijaksi kasva(tta)minen ohjelmoidussa yhteiskunnassa in Univeristy of Tampere 9.10.2015.
Scholz, A. (2014). *Smile TV*. Retrieved September 1, 2015, from:. http://www.creativeapplications.net/maxmsp/smile-tv-works-only-when-you-smile/
Stallman, R. M., Gay, J., & Lessig, L. (2009). *Free software, free society*. Hodder Christian Books.
Steiner, C. (2013). *Automate this: How algorithms took over our markets, our jobs, and the world*. Portfolio Trade.
Sterling, L. (2015). *An education for the 21st century means teaching coding in schools*.. Retrieved July 1, 2015, from:. http://theconversation.com/an-education-for-the- 21st-century-means-teaching-coding-in-schools-42046
Stiegler, B. (2005). *Manifesto*. Arsindustrialis.org. Retrieved April 1, 2015, from:. arsindustrialis.org/node/1472
Stiegler, B. (2010). *Manifesto*. Arsindustrialis.org. Retrieved April 1, 2015, from:. arsindustrialis.org/manifesto-2010
Thibodeau, P. H., & Boroditsky, L. (2011). Metaphors we think with: The role of metaphor in reasoning. *PLoS ONE*, *6*(2), 16782. http://dx.doi.org/10.1371/journal.pone.0016782
Thorp, J. (2009). *Just landed*. Retrieved August 1, 2015, from:. http://blog.blprnt.com/blog/blprnt/just-landed-processing-twitter-metacarta-hidden-data
Turkle, S. (2011). Alone together: Why we expect more from technology and less from each other. In *Basic books*.
University of California-Davis. (2007). China's eye on the internet. *ScienceDaily*,. Retrieved 21 july 2015, from:. www.sciencedaily.com/releases/2007/09/070911202441.htm
Vaden, T. (2005). Digital nominalism. Notes on the ethics of information society in view of the ontology of the digital. *Ethics and Information Technology*, *6*(4), 223–231. http://dx.doi.org/10.1007/s10676-005-0350-7
Vallance, C. (2015). *Car hack uses digital-radio broadcasts to seize control*.. Retrieved September 10, 2015, from. http://www.bbc.co.uk/news/technology-33622298
Wajcman, J. (2014). *Pressed for Time: The Acceleration of Life in Digital Capitalism*. University of Chicago Press.
Warschauer, M. (2004). *Technology and social inclusion*. MIT Press.
Washington, G. (2015). *84% of all stock trades are by high-frequency computers . . . only 16% are done by human traders*. Zero Hedge. Retrieved September 23, 2015, from. zerohedge.com/contributed/2012-17-26/84-all-stock-trades-are-high-frequency- computers-%E2%80%A6-only-16-are-done-human-tra
Weiss, G., & Wodak, R. (2006). Introduction. In G. Weiss, & R. Wodak (Eds.), *Critical discourse analysis: Theory and interdisciplinarity*. Palgrave Macmillan.
Williamson, B. (2015). Political computational thinking: Policy networks, digital governance and 'learning to code'. *Critical Policy Studies*, http://dx.doi.org/10.1080/19460171.2015.1052003
Williamson, B. (2016). Digital education governance: Data visualization, predictive analytics, and 'real-time' policy instruments. *Journal of Education Policy*, *31*(2), 123–141. http://dx.doi.org/10.1080/02680939.2015.1035758
Wilson, M., Scalise, K., & Gochyyev, P. (2015). Rethinking ICT literacy: From computer skills to social network settings. *Thinking Skills and Creativity*, http://dx.doi.org/10.1016/j.tsc.2015.05.001

Publication 2

Dufva, T.. Maker Movement: Creating knowledge through basic intention. Techne Series – Research in Sloyd Education and Craft Science, 24 (2), 129-141.. 2017

Maker Movement

creating knowledge through basic intention

Tomi Dufva

Maker movement is often celebrated as a rekindled interest in making by hand, as well as a promise for new forms of manufacturing and economic growth. In contrast to this popularized image, the theoretical background in the maker movement remains ambivalent. This article takes a look at the theoretical foundation of the maker movement and proposes a phenomenological approach to making by hand as a framework for maker movement.

A particular focus is on the knowledge making process in the maker movement following Finnish craft researcher Kojonkoski-Rännäli's account of making by hand. Basing her theory on Martin Heidegger's philosophical analysis, Kojonkoski-Rännäli sees making by hand an essential way of existing in the world: making by hand develops not only maker's handicraft skills but also her/his knowledge, responsibility and caring for the world as it appears to her/him through the act of making.

In this paper, I explore maker movements' relation to Kojonkoski-Rännäli's philosophy of making by hand. Moreover, I focus on how the maker movements approach to digital and digitalization relate to making by hand.

Keywords: Maker movement, code literacy, craft education, philosophy, making by hand

Introduction

In recent years there has been a growing interest towards the maker movement (also referred to as the maker culture). It has been touted to bring engineering and making by hand back to the western countries as well as to create new possibilities in the developing countries (See for example: Anderson, 2012; Halverson & Sheridan, 2014; Lang, 2013; Lindtner, 2015). In short, Maker movement has effects on manufacturing, culture as well as education.

Making in maker movement is seen as empowering as well as entrepreneurial (Lang, 2013). Makers take advantage of new manufacturing methods and the collective powers of the internet but also value handicraft skills. Still, most of the focus is on either the making processes or the commercial opportunities, than in the theoretical aspects of the maker movement.

In a hands-on book "Invent to Learn" Martinez and Stager tie maker movement closely to Piagetian pedagogical ideas and even to Rousseau's views on childhood (Martinez & Stager, 2013). Papert's views on using computer's in education are also often associated with the maker movement (Halverson & Sheridan, 2014; Martinez & Stager, 2013; Papert, 1980). Some of the ideas in maker movement are further developed by STEM & STEAM initiatives in the United States, and similar in the United Kingdom, and for example, in Finland. Common to these developments are the focus on science, technology and engineering aspects of the maker movement (James-Thomas, 2014; Mykkänen & Liukas, 2014; "National STEM Centre ," 2015; "STEAM: A Framework for Teaching Across the Disciplines," n.d.; "STEM to STEAM," 2016).

In this article, I want to expand on the theoretical side of the maker movement by comparing it to the Finnish craft researcher Kojonkoski-Rännäli's theories on making. All though her ideas relate to, and can be traced to, many other craft researcher views, I am basing my research mostly on the concepts she has developed in her work. Her ideas create a profound philosophical connection to phenomenological studies and connect making to deep ontological issues. Moreover, I am using some of the concepts she has defined as a frame of reference to look at the maker movement. My aim is not to give a general theory or educational method of the maker movement, but rather to show how some of the practices in the maker movement may have the abilities to create deep sense-making into our digitalized world.

Digital divide, a concept that was formerly used to describe the divide to those who had access to the internet and those who did not, could now be used to describe the gap between people who understand digital technology and those who do not (Digital Divide, 2011; Warschauer, 2004). My interest in this article lies in the possibility of if and how maker movement could be seen as a tool to bridge the gap of the digital divide, i.e., bring understanding to the digital world we live in.

In the next section, I define the maker movement more comprehensibly, as well as present some of the criticism towards the maker movement. Then I will expand on Kojonkoski-Rännäli's ideas on making and relate her work on a more larger context of the philosophy of making. The two last chapters will explore how the maker movement relates to Kojonkoski-Rännäli's ideas and outlines some of the outcomes of this method.

From bits to atoms - question of maker movement

A new way of making, or a new industrial revolution?

The understanding of the maker movement is multifaceted. It is seen as a remedy, as a cultural movement as well as a new pedagogical method. Naturally, all of these ideas overlap each other, rather than contradict each other, but choose to emphasize different qualities or notions of the maker movement.

The maker movement is often associated with the rekindled interest in hardware design and manufacturing accompanied by the proliferation of inexpensive production tools (Anderson, 2012; Halverson & Sheridan, 2014). The Internet has helped in expanding the maker movement into a global movement, often connecting people in ways that otherwise would have been unlikely. Chris Anderson, a former editor-in-chief of Wired magazine and the author of "Makers: The new industrial revolution" calls the maker movement a new industrial revolution which happens "when the web generation turns to the real world" (Anderson, 2012, p. 42). As such The movement is celebrated as a new way to create more ideas and products that otherwise wouldn't have been possible (Anderson, 2012; Buechley, 2014; Hatch, 2013; MacMillan, 2012; Martinez & Stager, 2013; Mellis & Buechley, 2014).

However, to think of the maker movement merely as an interest in affordable production, manufacturing platforms or creation of novel products is somewhat misleading. Dougherty, the founder of Make magazine, - a magazine aimed at enthusiastic makers, describes makers as enthusiasts who want to explore the possibilities of both new and old technology (Dougherty, 2012b). Similarly, Martinez and Stager tie the maker movement to constructionism finding it as an invigorating way of utilizing constructionism, even if the practitioners are not aware of the underlying formal knowledge (Martinez & Stager, 2013). The maker movement is seen to blend the formal and informal learning together. This blending can happen through the emphasis on the making, instead of theory, as well as through using makerspaces as educational space (Blikstein & Krannich, 2013; Halverson & Sheridan, 2014).

Dougherty refers to Dewey's views on education in his article on the maker movement emphasizing Dewey's belief in learning by doing (Dewey, 1998; Dougherty, 2012b). Martinez and Stager walk on the same lines and trace the roots of the maker movement to constructivist learning theory, to the Reggio Emilia approach as well as to the Piagetian idea that to understand is to invent (Martinez & Stager, 2013). In these approaches, maker movement is seen as a tool to gain necessary 21st-century skills, a digital age pedagogy and continuation of the works of Dewey, Piaget and later Papert's ideas about the use of computers in education (Blikstein & Krannich, 2013; Halverson & Sheridan, 2014; Papert, 1980). Just as a pencil or brushes give opportunities to explore the visual world with lines and colors, the maker movement gives tools for the exploration of digital and electronic techniques.

The maker movement's educational views can also be seen from the critical pedagogue's standpoint. By offering a critical understanding of our everyday digital products, making can empower the user in the digital world. Furthermore, makerspaces, hackerspaces or FabLabs offer tools and tutoring on various subjects of making. This can help democratize the tools and production as well as engage communities in working together (Halverson & Sheridan, 2014; Konopasky & Sheridan, 2015; Mellis & Buechley, 2014).

Or just a continuation of the Arts & Crafts movement?

The Maker movement can also be seen as a continuation or as a new version of the 20th-century Arts & Crafts movement. It does share similar goals, such as giving people the freedom to not be satisfied with monotonous industrial products and the possibility of breaking free from tedious corporal jobs to find more meaningful jobs in self-employment (Morozov, 2014b; Patokorpi, 2014). However, unlike the Art & Crafts movement, which failed in producing anything of great usefulness or value to ordinary people (Morozov, 2014b), the maker movement might just have found suitable niches to serve in the global marketplace (Hatch, 2013).

On the downside, the commodification of the maker movement can already be seen everywhere. More and more products that might have little to do with the maker ethos are marketed for budding makers to be. The danger being that the theory of learning by doing might be commercialized to products that fail to teach anything about making and working with your own hands. Moreover, at the same time the real products, the ones we use every day, are left to professionals and are further enclosed through hamper-free bolts and proprietary software. This is the exact opposite of the ideology of curiosity, openness, and exploration inherent in the maker movement.

Furthermore, the maker movement is criticized as serving a relatively small percentage of the maker population. For instance, Leah Buechley, a former professor at MIT, has criticized the maker movement as being mostly targeted to wealthy white males (Buechley, 2014; Halverson & Sheridan, 2014). Her criticism targets primarily the Make-magazine, -a prominent publication for the makers-, but these problems connect more widely to the consumeristic aspects of the maker movement, and point out problems that should be addressed in the maker movement.

The way back from digital

Despite the criticism, the maker movement does include a diverse field of practitioners. One of the difficulties in describing the maker movement might just be its varied and multidisciplinary nature. As already stated the maker movement can be seen from the constructivist perspective as an educational tool, or from the economic view as a new entrepreneurial possibility. Alternatively, it can be criticised as being a fad and continuation of the neoliberal agenda or it can be seen as offering democratizing and empowering tools for everybody (Halverson & Sheridan, 2014; Mellis & Buechley, 2014). In addition, the maker movement can also be associated to the DIY-movement, hacker culture and to free and open software cultures (Gauntlett, 2013; Levy, 1984; Lindtner, 2015; Söderberg, 2007; Tochetti, 2012).

These diverse subcultures give the maker movement a unique twist as well as varied character. Moreover, the maker movement has gained a widespread attention over the globe. From studies of Chinas maker spaces (Lindtner & Li, 2012; Lindtner, 2015) to the new emergence of DIY synthetic biology (Tochetti, 2012) the movement has accelerated from hobbyist movement into a global force (Hatch, 2013).

In sum, the maker movement conveys the idea of makers that can utilize new digital tools, such as 3D-printers or laser cutters or even biotechnology, but at the same time, it celebrates the lost arts of traditional handicraft skills (Anderson, 2012; Lang, 2013). It is also a societal and political movement, closely tied to hacker culture and open software & hardware movement as well as it is a new commercial trend ("Maker-kulttuurissa vertaisuus ja avoimuus ovat oppimisen käyttövoimia | Sitra," n.d.; Morozov, 2014b; Patokorpi, 2014). Moreover, it can be seen as an empowering platform for children and adults, enabling new ways of expression and understanding (James-Thomas, 2014; Lang, 2013).

One possible common idea in all of these interpretations might be what Anderson calls "Bits to Atoms" (Anderson, 2012). The idea being that the new manufacturing methods, such as 3D-printing bring digital bytes back to the "real" physical world. This notion can be seen to some extent to complete the circle of digitalization; In his famous book "Being Digital" Negroponte proclaimed that everything that can be digitized will be digitized; that the life will move from atoms to bits (Negroponte, 2015). For Anderson, the idea of bits back to atoms completes the circle of digitalization, but it could be seen as being the common thread of all of the interpretations of the maker movement: a way of making by hand in the digitalized era.

Kojonkoski-Rännäli's phenomenological philosophy of making

To give a different perspective on to the maker movement, I am going to contrast it with the philosophy of doing by hand and more specifically to Kojonkoski-Rännäli's writings (2016, 2014, 1995)Doing by hand has deep connections to our being and understanding of our being as well as the world around us. Kojonkoski-Rännäli has focused on this knowledge making process and offers detailed and exciting views on making by hand (2014, 1995).

Unfortunately, most of her writing is in Finnish, making the use of her research problematic to other than Finnish speakers. At the end of this chapter, I will connect her thinking to other researchers' views on the craft to connect her research to a broader picture. However, the aim of this article is not only to present Kojonkoski-Rännäli's work but rather use some of her concepts as a lens to look at the maker movement.

Kojonkoski-Rännäli first formulated her views of the philosophy of craft in her dissertation *Ajatus käsissämme: Käsityön käsitteen merkityssisällön analyysi* [Thought in our hands: an analysis of the meaning of the concept handicraft] (1995). She has further developed her ideas in her recent book "Käsin tekemisen filosofiaa" ("The philosophy of doing by hand") (Kojonkoski-Rännäli, 2014). In these books, she offers interesting perspectives on making. For Kojonkoski-Rännäli making by hand is existing in the world: Humans have intention in their making. As active bodily creatures, doing by hand is customary to our being; thus it is fundamental to our way of being in the world.

Kojonkoski-Rännäli backs her theory with Martin Heidegger's philosophical analysis on being (Heidegger, 2009). According to Heidegger, the way in which we exist in the world is by dwelling (wohnen). This existing, living, is realized through making (bauen). In this way doing by hand is one of the core components of existing in the world.

Kojonkoski-Rännäli further analyzes the basic concepts of doing by hand with Heidegger's concept of ready-to-hand (zuhandenheit) which, according to Kojonkoski-Rännäli, is more direct and immediate than perceptual experience. Kojonkoski-Rännäli sees Heidegger's ready-to-hand (zuhandenheit) to be near to Merleau-Ponty's concept of grasping: We can already grasp something before we know it. (Merleau-Ponty, 2015). In Finnish language, grasping can be translated to a word käsittää, which means understanding through hands (Kojonkoski-Rännäli, 1995).

This form of knowledge creation predates intellectual comprehension. Thus existing occurs primarily through bodily experience. In this way, Kojonkoski-Rännäli sees that making by hand is essential to human existence. Relating making by hand to Heidegger's concept of making (bauen) Kojonkoski-Rännäli notes that making is not only an act of creating an artifact but that it also includes aspects of caretaking and belonging to the world the maker creates. Heidegger calls thus this making as "tending" of the world, an act that creates deep connections between the maker and the world (Heidegger, 2009; 2005). In a similar note, Kojonkoski-Rännäli calls this grasping of the world the original work of man, giving emphasis on the making as a core function of being (Kojonkoski-Rännäli, 1995).

From existing to creating a relationship with the world

However, for Kojonkoski-Rännäli craft is not just a bodily experience, but also a skill to be mastered: Craft needs both practice and knowledge. When immediate grasping-being in the world happens together with comprehension acquired through practice and intellectual knowledge, Kojonkoski-Rännäli calls the act of making a basic intention.

The concept of basic intention is important in Kojonkoski-Rännäli's work as it describes both the importance of making by hand and the optimum way of making by hand.

> When the maker is both experientially and emotionally attached to her work as well as rationally, and intentionally, then the maker gains knowledge of her material and the world wherein she belongs to, writes Kojonkoski-Rännäli. She continues:
>
> …she gets to know the possibilities of her work and her limits. She is engaged with her material and feels responsibility for her work. For these reasons, I entitle the intention of making as the basic intention. (Kojonkoski-Rännäli, 1995, p. 48 translation by article author)

To further illustrate her meaning of basic intention, Kojonkoski-Rännäli uses the Greek term techne (tekhniké) to describe further the process of making. Techne has a dual meaning. It can be understood as a making by hand, as an art, as being able to do something. On the other hand, it can also be interpreted as understanding and knowing in its widest possible meaning: as surviving and accomplishing something in the world (Kojonkoski-Rännäli, 1995).

Techne is making that brings forth something that can't come out itself, but which has the possibility to arise. For example building a house or a boat can be such making (Heidegger, 2009; Kojonkoski-Rännäli, 1995). For Kojonkoski-Rännäli techne fuses knowing and doing into one: problem-solving and molding of the material, thinking and motor skills are closely combined.

Techne also implies that basic intention demands the maker to be personally involved in the whole process of making: From planning to the finished product. According to Kojonkoski-Rännäli, this intentional process creates knowledge not only of the material and making of the artifact but also of the world around it. Furthermore basic intention binds the maker ethically and empathetically to the surrounding world (Kojonkoski-Rännäli, 1995).

This ethical and emphatic connection is an important aspect of basic intention as it, along with the real artifact, creates inner qualities, physical and psychological capabilities, and characteristics of the maker

(Kojonkoski-Rännäli, 1995). For Kojonkoski-Rännäli making with basic intention is an important contemporary and future skill as it develops makers creative skills to deal with open-ended and multi-faceted problems of modern life (de Vries & Mottier, 2006; Kojonkoski-Rännäli, 2006; 2014).

Head, hand and heart

Kojonkoski-Rännäli's philosophy bares many similarities to other craft researchers' studies. For instance, the importance of making by hand as an important 21st-century skill (Vanada, 2014; Veeber, Syrjäläinen, & Lind, 2015; Wright & Davis, 2014). In combining head, heart, and hand as the most important characteristics of craft and making by hand, Kojonkoski-Rännäli's research echoes many other craft researchers. (e. g. Peach, 2012; Sennett, 2009). Kojonkoski-Rännäli's theories on making as a part of knowledge making and growing processes also bear a resemblance to Dewey's philosophy on making and education (Dewey, 1998). In a recent debate 1 in Finland, Kojonkoski-Rännäli amplified her views on making by hand, citing Risatti that craft is something that is done using hands or with hand tools and by molding concrete materials, combining theoretical, abstract knowledge into practical making process (Sinervo, 2013; Risatti, 2009). Notable in Kojonkoski-Rännäli's research is that by the concept of basic intention she clarifies and deepens the significance of making by hand.

Basic intention of the digital era

The disintegration of the making process

The problem for Kojonkoski-Rännäli is that modern making often includes automated machinery, pre-designed parts, instructions, or other aspects that distance the maker from the making process. Making in this way distances making from the original experience of doing by hand, and the connection maker has with the material happens only on an intellectual level. The intellectual emphasis further separates our rational thinking from the rest of our embodied experience, preventing the basic intention of making happening.

Furthermore, the differentiation between body and mind weakens our comprehension of nature, and the inherent connection we have with nature. The act of making becomes only a vehicle for something. The work and the process have no value on their own. Kojonkoski-Rännäli calls this the instrumental intention (Kojonkoski-Rännäli, 1995).

Kojonkoski-Rännäli does not directly address maker movement in her work. 2 Although, in her recent book and blog posts, she acknowledges that making is gaining traction and recognizes, for instance, the Pro-AM (Pro-amateur) movement and craftivism (craft + activism) as ways in which making is both renewing as well as sustaining itself (Kojonkoski-Rännäli, 2006).

Regardless, Kojonkoski-Rännäli doubts whether making that is done through modern technology is ever able to give its maker the same kind of feeling nor knowledge that one acquires through making with basic intention. Machinery creates abstractions and distance that take away the characteristics of the basic intention. By forwarding some stages of the process to machine or automated processes, we lose the grasp of that process and the world connected to it (Kojonkoski-Rännäli, 1995, 2012).

Owning the digital technology

However, maker movement might offer some ways of working that may counterbalance the automation and distancing aspects of modern technology. The maker movement could be seen as a way to bring basic intention into the modern technological craft making processes. I will first compare some of the similarities of the maker movement and basic intention, and on the next chapter provides two example case to illuminate my meaning.

On a general level, the maker movements manifesto, coined by Mark Hatch (Hatch, 2013, p.11-31.) seems to share many characteristics with Kojonkoski-Rännäli ideas on making. They both see it as fundamental to our being and as a way of experiencing the world. They both stress the wholeness of the process of making: that it is embodied knowledge together with intellectual knowledge.

These qualities tie the maker movement to a craft education on a more general level. Veeber, Syrjäläinen and Lind allege that craft education, and making by hand, is an important 21st-century skill. By making we advance the understanding of diversity and challenges in life (Veeber et al., 2015). This signifies a similar aspect of making than Kojonkoski-Rännäli: That making is not only skill to be mastered but a way of meaning-making and existing in the world (Kojonkoski-Rännäli, 1995).

Besides sharing similarities with modern craft research, the maker movement can offer altogether fresh perspectives to making with digital technologies. One of the foundations of the maker movement is a curiosity to look under the hood, the aspiration to not only consume but to understand technologies. ”If you can’t open it, you don’t own it” goes the famous maker motto, emphasizing the importance of knowing your way around your machines (Anderson, 2012; Lang, 2013). The way maker movement approaches technology may provide modern maker with tools and skill sets that offer direct, graspable, knowledge on things Kojonkoski-Rännäli sees as automated and distancing (Kojonkoski-Rännäli, 1995, 2014)

Sense-making in the digital world

The relation between making by hand and digitality is complex and far reaching. It encompasses discussions from technical perspectives to the philosophical debates on the post-human. My aim here is first to present two example problems inherent in the digital making. Then I suggest ways how these problems could be seen from the view of the maker movement and how the maker movements attitude towards making could be considered as a making with basic intention.

Abstracted and invisible

The first problem stems from the nature of digital technology. Digitalization of tools has created an abstraction into making process. This means that some part of, or even the whole tool is presented by software, by digital bits.

The software itself is an abstraction: through code, software represents the structure and logic of the tool. That code is then run on the digital device that interprets the code and runs the software. The outcome is a reprogrammable instrument that has abilities beyond ”normal” physical tools: The tool can be changed, reprogrammed on the fly, without changing any physical parts of the device. The drawback is that the abstraction makes some of the functionality of the tool invisible: Part of the making process becomes detached. Furthermore, without the maker being able to read that invisible code the ”how does this tool work” becomes unclear, or even magical.

Rapidly advancing technology can create products that may have been unthinkable only a few years ago. Mobile phones, smart watches, predictive algorithms (e.g. Google’s search suggestions) and the advances in machine learning (e.g. intelligent assistants such as Apple’s Siri or Google’s Now) all have features that may fill us with wonder.

Marketing and popular culture have further emphasized the amazing and magical aspects of technology. The way digital products are presented in commercials as life changing and unbelievable or how tv-series represent computer viruses, or AI (artificial intelligence) gives us the impression of the digital as a supernatural entity. This popularization of the digitality abstracts the abstract nature even further. (Lanier, 2010; Morozov, 2014a; Rushkoff, 2010; 2013).

As mentioned earlier the digital technology differs from other technologies in that it is programmed. The code is in the heart of every digital technology and substantially shapes its behavior. Code shares only an indirect connection to the physical nature where we live in through the electronic, physical layer of the device. Otherwise, the products created in the digital realm are indifferent to the physical world and its laws: An apple falling from a tree in the virtual world does not have to fall at all. The only way for it to fall is through someone coding the falling mechanism into it. This makes it hard to have preconceptions of the ways digital tools or methods behave. In other words, digitality and programming create a world is difficult to grasp or understand.

We might have the knowledge how to use modern tools, be it a digital camera, a dishwasher or a software tool such as Adobe Photoshop, but we usually do not have the understanding of how they work. Thus, the possibilities to form emotional, experiential connection, or embodied connection toward digital becomes challenging.

The problem of the black box

The second problem could also be seen as another way of looking at the same problem. While the abstract nature of code is inherent in digital technology's nature, it is also affected by the politics governing it. Patent laws, copyrights and proprietary software create a wall between the user and the process.

Proprietary software means software where the user has no possibility, or right, to see the way the software is built i.e. to read the devices source code (Stallman, Gay, & Lessig, 2009). When the user cannot see how the program is constructed, he or she must rely on the outcomes of the software, making the software a black box without any access. Similar barriers are created by copyright and patent laws, disabling makers from creating their versions of the tools even if they figure out the way the tool is built.

These kinds of restrictions create a societal and a political barrier that can be understood from the neoliberal economic point of view, but because of the aforementioned nature of the code, creates an obstacle that hinders the basic intention happening in the making process. Furthermore, these restrictions may alienate the maker from her/his tools by retaining part of the ownership of the instrument to themselves and discouraging the maker of tinkering with the device.

Hacking into the digital world

Maker movement, as a movement born of the digital age, offers some ways of addressing these problems. For instance, by taking control of the black boxed processes. "If you cannot open it you do not own it" -ethos contains an idea of getting to know the insides of the machines and taking back control of the devices (Hatch, 2013; Martinez & Stager, 2013). A research project done at MIT Media Lab Buechley and Mellis held workshops on creating a working mobile phone from DIY-materials. One of the results of the study was the increased understanding of the formerly obscure technology. At the same time, the understanding promoted critical thinking and engagement (Mellis & Buechley, 2014).

This empowerment may result to both in an activity where maker learns how programming or other technologies work, but also to a political stance that questions the purposefulness of proprietary software and hardware. As such maker movement may be seen to eliminate the invisible and abstract parts of the code.

Hacking, a term originating from the software world, meaning the unintended or clever use of the code or software can now be seen to have spread into the physical world through the maker movement, as suggested by Dougherty (Espinoza, 2014). Steven Levy describes hacking as closely related to maker movement's ethos:

> Hackers believe that essential lessons can be learned about the systems – about the world – from taking things apart, seeing how they work, and using this knowledge to create new and even more interesting things (Levy, 1984, p. 27–36.)

Hacking in the maker movement consists of the opening of both physical (machines) and abstract (software) products, by which a maker gets to know how the products or tools operate by way of doing by hand. One of Kojonkoski-Rännäli's thoughts of basic intention is that making is tending, a way of taking care and belonging to the surrounding world. Through the ethos of hacking it is possible to draw a correlation between the Kojonkoski-Rännäli's tending of the world and the maker movements caring of the digital world (Hatch, 2013; Kojonkoski-Rännäli, 1995).

Making in the maker movement is seen as a way of looking at the world and suggesting new possibilities to existing in the world (Martinez & Stager, 2013). Even though the maker movement did not start the free software movement or open source movement – the movements which are providing alternatives to closed proprietary software – it can be seen to embrace the ideologies of these movements. By promoting makers rights to read, and even write the code, the maker movement partakes into the tending of the digital world; Who of us would like to live in a world where making is restricted?

This care-taking and engagement can be seen clearly in the popularity of various online forums, websites and mailing lists as well as in real-world gatherings, such as Maker Faires (Dougherty, 2012a; Branwyn, 2015). Lang further emphasizes the communal parts of the maker movement, naming it as the DIT (Do-IT-Together) culture (Lang, 2013).

In sum maker movement could be seen as a way of creating belonging to the world that is vastly digitalized, or to put it another way around, the maker movement belongs to both the ”real” and the digital world.

Digital hands?

Another important aspect of basic intention in the making process is the direct use of hands, or tools worked directly by the hand. In comparison, many of the digital tools often touted as a central part of the maker movement, such as 3D-printers rely on automating parts of the process and fall out of the category of direct use. However, the hacker ethos, along with the empowered control of the machines may provide a different interpretation.

Common users of digital manufacturing tools might be satisfied with using the tools in the ways it was intended and instruction to be used. However, maker movement encourages the maker to go further, encouraging the maker not just to learn how the tool works, but also to hack and reprogram the instrument to work in ways the maker feels most comfortable. In the process, the maker gets to see inside the black box and make it their own.

Many makers feel a kind of pride and engagement over their machines. The artifacts produced by them are shaped by the code created by the makers themselves (Lang, 2013). In other words, the difference between makers use versus the standard use of these tools could be seen as the difference between using a program, for example, image editor versus creating the program themselves.

Even if the result comes from a tool that automates some processes, these processes can be seen to be in direct control of the maker: She/he can alter the process, work directly with the code and see the results of her actions. This can lead to a knowledge that is not only intellectual but embodied in the maker himself. The abstract code can become a graspable process, wherein the maker feels to be deeply involved in.

For example, coding is seen as a craft by many developers and as such displays many of the characteristics of craft: Developers feel deep connection and responsibility of their code and even of the process and tools of writing that code (Cox, 2013). The fact that code is run on automatized machines and is digital does not seem to hinder the way developers feel about their code (Feller, Fitzgerald, Hissam, Lakhani, 2005).

A research project by Buechley and Perner-Wilson integrates many of these characteristics of the maker movement. In their project Buechley and Perner-Wilson demonstrated alternative ways of making electronics: Instead of using ready-made components, they constructed their own by carving, sewing and painting. The results displayed how such informal and hands-on approach expand makers understanding of electronics as well as create strong emotional connections to the electronic devices (Buechley & Perner-Wilson, 2012).

These two examples aim to clarify the depth of the maker movement and suggest ways how the basic intention might be seen happening, through the maker movement, in the digital world. Seymour Papert planned already in 1970's that computers should become like modeling clay or paper maché, moldable material that creates connections between the maker and the digital world (Martinez & Stager, 2013; Papert, 1980). It seems that maker movement has the potential to accomplish this plan.

Conclusion

As Kojonkoski-Rännäli proposes, making by hand is fundamental to humans as a way of existing and comprehending the world. Doing by hand is an important skill that should not be ignored in the age of information technology (Kojonkoski-Rännäli, 2006; 2012; 2014; 2016). Kojonkoski-Rännäli does not oppose modern technology per se but is concerned that it might hinder the connection humans have with the act of making. Automatized and closed processes may take away the wholeness of the making process, lessening the connection maker has with the object and diminishing both the inner and outer skills and abilities maker gains in the process (Kojonkoski-Rännäli, 1995, 2014).

The ubiquitous nature of the digital has altered the ways in which we exist in the world. The constructions of our society are as much digital as they are concrete. (T. Dufva & Dufva, 2016; Rushkoff, 2010; Warschauer, 2004). This being, existing in two worlds simultaneously emphasize the importance of understanding the digital world. If we do not comprehend the world we live in, how can we live or change it?

This article suggests the maker movement as a method of looking at the making by hand processes in the digital era. Through the maker movements ideology as well as the way the maker movement approaches digitality of modern making, it suggests ways how the basic intention could be possible in the digital era. Enthusiasm, open-ended inquiry, hacking, owning technology and curiosity can be seem to be important aspects in grasping digitality.

By empowering the makers to hack into their digital devices and make them their own, the maker movement makes the invisible digital processes invisible and even as an integral part of the making process. On the other hand, by disclosing both the abstract nature, as well as cultural, economic and political aspects of digital, the maker movement shows it care-taking, an ethical and emphatic relationship it shares with the digital world.

As this paper takes only a theoretical look at the making process, it does not claim that this is the case, but it does offer possible and far-reaching outcomes of maker movement that are often not considered when talking about maker movement. Even if the maker movement is heralded as the new industrial

revolution and at the same time criticized as a wealthy white's males free time, it could provide us with a set of tools and skills needed in the digital age.

1 In 2013, The Craft Museum of Finland chose cake-artist Emma Iivanainen as a maker of the year, which draw intense discussion in the craft circles about what can be called craft and what cannot.

2 On a very recent website, article Kojonkoski-Rännäli deals directly with the maker movement and many of the questions raised here, mostly based on an article I co-wrote and onto conference presentation I had concerning this article. (Kojonkoski-Rännäli, 2016), (M. Dufva & Dufva, 2016).

References

Anderson, C. (2012). *Makers: The New Industrial Revolution.* London: Random House.

Blikstein, P., & Krannich, D. (2013). *The makers' movement and FabLabs in education:*

experiences, technologies, and research (pp. 613–616). Presented at the In Proceedings of the 12th International Conference on Interaction Design and Children (IDC '13), New York, New York, USA: ACM. http://doi.org/10.1145/2485760.2485884

Branwyn, G. (2015, April 16). *Looking Back at the Launch of the Maker Movement: The First Maker Faire.* Retrieved May 20, 2015, from http://makezine.com/2015/04/16/looking-back-launch-maker-movement-first-maker-faire/

Buechley, L. (2014,10. 31). Eyeo 2014 - Leah Buechley. Retrieved from: https://vimeo.com/ 110616469

Buechley, L., & Perner-Wilson, H. (2012). Crafting technology: Reimagining the processes, materials, and cultures of electronics. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 19(3), 21. http://doi.org/10.1145/2362364.2362369

Cox, G. (2013). *Speaking Code.* Cambridge: MIT Press.

de Vries, M., & Mottier, I. (2006). *International Handbook of Technology Education.* New York: Springer International Publishing.

Dewey, J. (1998). *Experience and Education.* New York: Kappa Delta Pi.

Digital Divide. (2011). Digital Divide. Berlin/Heidelberg: Springer-Verlag. http://doi.org/10.1007/SpringerReference_61942

Dougherty, D. (2012a). *Maker Market Study:* (pp. 1–32). Sebastopol: Make Magazine.

Dougherty, D. (2012b). The Maker Movement. *Innovations: Technology, Governance, Globalization,* 7(3), 11–14. http://doi.org/10.1162/inov_a_00135

Dufva, M., & Dufva, T. (2016). *Käsin kosketeltava digitaalisuus.* Futura, 35, 44–49.

Dufva, T., & Dufva, M. (2016). Metaphors of code—Structuring and broadening the discussion on teaching children to code. *Thinking Skills and Creativity,* 22, 97–110. http://doi.org/10.1016/j.tsc.2016.09.004

Espinoza, M. (2014, May 11). *Sebastopol's Dale Dougherty out to remake the world.* Retrieved November 21, 2015, from http://www.pressdemocrat.com/none/1862515-181//article/20140510/ARTICLES/140519980/

Feller, J., Anderson, R., Lessig, L., McGowan, D., OMahony, S., Kelty, C., et al. (2005). Perspectives on Free and Open Source Software. (S. A. Hissam, J. Feller, K. R. Lakhani, & B. Fitzgerald, Eds.) *Journal of Information Technology & Politics,* 4,538–99. MIT Press. http://doi.org/10.1080/19331680801916908

Gauntlett, D. (2013). *Making is Connecting.* Cambridge: John Wiley & Sons.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 492–494. http://doi.org/10.17763/haer.84.4.b1p1352374577600

Hatch, M. (2013). *The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers.* New York: McGraw Hill Professional.

Heidegger, M. (2009). *Vortrage und AufsÄtze (Pfullingen)* (11 ed.). Stuttgart: Klett-Cotta. Original work published 1952.

Heidegger, M. (2005). Introduction to Phenomenological Research. Bloomington: Indiana University Press.

James-Thomas, A. (2014). Making makers : kids, tools, and the future of innovation. Sebastopol: Maker Media.

Kojonkoski-Rännäli, S. (1995). *Ajatus käsissämme. Käsityön käsitteen merkityssisällön analyysi.* Turun yliopisto, Rauman opettajankoulutuslaitos. Nide 109 / Turun Yliopiston julkaisuja. Sarja C.

Kojonkoski-Rännäli, S. (2006). *Tulevaisuuden käsityötaito.* Futura 25(1).

Kojonkoski-Rännäli, S. (2012). *Kriittistä käsityökasvatusta ja radikaalipedagogiikkaa.* Retrieved march 12, 2017, from:https://blogit.punomo.fi/saikeita/2012/02/22/kriittista-kasityokasvatusta-ja/

Kojonkoski-Rännäli, S. (2014). *Käsin tekemisen filosofiaa.* Turun yliopisto - Opettajankoulutuslaitos, Rauman yksikkö.

Kojonkoski-Rännäli, S. (2016, November 24). *Käsin tekeminen, digitaalinen tekeminen ja uusi tekijä-liike*. Retrieved November 25, 2016, from https://punomo-static.npn.fi/uploads/2016/11/kasin-tekeminen-digitaalinen-tekeminen_seija-kojonkoski-rannali.pdf

Konopasky, A., & Sheridan, K. M. (2015, April 14). *An Experimental Study Comparing Two*

Educational Approaches to Making With Simple Circuits. an Educational Research Association

annual meeting. Chicago, IL.

Lang, D. (2013). *Zero to Maker.* Sebastopol: Maker Media.

Lanier, J. (2010). *You Are Not a Gadget.* New York : Alfred A. Knopf.

Levy, S. (1984). *Hackers: Heroes of the computer revolution.* Garden City, N.Y: Anchor Press/Doubleday.

Lindtner, S. (2015). Hacking with Chinese Characteristics: The Promises of the Maker Movement against China's Manufacturing Culture. *Science*, 40(5), 854–879. http://doi.org/10.1177/0162243915590861.

Lindtner, S., & Li, D. (2012). Created in China: the makings of China's hackerspace community. *Interactions*, 19(6), 18–22. http://doi.org/10.1145/2377783.2377789.

MacMillan, T. (2012, April 30). *On State Street, "Maker" Movement Arrives*. Retrieved November 15, 2014, from http://www.newhavenindependent.org/index.php/archives/entry/make_haven/

Maker-kulttuurissa vertaisuus ja avoimuus ovat oppimisen käyttövoimia | Sitra. (n.d.). *Maker-kulttuurissa vertaisuus ja avoimuus ovat oppimisen käyttövoimia* | Sitra. Retrieved October 26, 2015, from http://www.sitra.fi/blogi/maker-kulttuurissa-vertaisuus-ja-avoimuus-ovat-oppimisen-kayttovoimia

Martinez, S. L., & Stager, G. (2013). *Invent to Learn.* (C. Sinclair, Ed.) (1st ed.). Torrance: Constructing Modern Knowledge Press.

Mellis, D. A., & Buechley, L. (2014). Do-it-yourself cellphones: an investigation into the possibilities and limits of high-tech diy. *the 32nd annual ACM conference (*pp. 1723–1732). New York, New York, USA: ACM. http://doi.org/10.1145/2556288.2557309

Merleau-Ponty, M. (2015). *Phenomenology of perception*. London: Forgotten Books.

Morozov, E. (2014a). *To Save Everything, Click Here*. New York: PublicAffairs.

Morozov, E. (2014b, January 13). *Hackers, Makers, and the Next Industrial Revolution.* Retrieved January 29, 2014, from http://www.newyorker.com/arts/critics/atlarge/2014/01/13/140113crat_atlarge_morozov

Mykkänen, J., & Liukas, L. (2014). *Koodi 2016*. Helsinki: Lönnberg Print.

National STEM Centre. (2015). *National STEM Centre.* Retrieved January 3, 2015, from http://www.nationalstemcentre.org.uk/stem-in-context/what-is-stem

Negroponte, N. (2015). *Being Digital.* New York: Alfred A. Knopf.

Papert, S. (1980). M*indstorms: children, computers, and powerful ideas.* Basic Books, Inc. New York: Alfred A. Knopf.

Patokorpi, L. (2014). *"The Art and Craft of the Machine"* Tampereen yliopisto,

Kieli-, käännös- ja kirjallisuustieteiden yksikkö, Englantilainen filologia.

Retrieved from https://tampub.uta.fi/bitstream/handle/10024/95658/GRADU-1402572504.pdf?sequence=1

Peach, A. (2012). On Craftsmanship: Towards a New Bauhaus. *The Journal of Modern Craft*, 5(2), 241–243. http://doi.org/10.2752/174967812X13346796878319

Risatti, H. (2009). *A Theory of Craft.* Chapel Hill: Univ of North Carolina Press.

Rushkoff, D. (2010). *Program Or Be Programmed.* New York: OR Books.

Rushkoff, D. (2013). *Present Shock.* New York: Penguin..

Sennett, R. (2009). *The Craftsman.* London: Penguin.

Sinervo, P. (2013, April 16). *Onko kakun tekeminen käsityötä?* Retrieved October 1, 2015, from https://blogit.punomo.npn.fi/saikeita/2013/04/16/onko-kakun-tekeminen-kasityota/

Söderberg, J. (2007). *Hacking Capitalism, The Free and Open Source Software Movement (Routledge Research in Information Technology and Society),* New York: Routledge.

*S*tallman, R. M., Gay, J., & Lessig, L. (2009). *Free Software, Free Society.* Boston: Free Software Foundation.

STEAM: A Framework for Teaching Across the Disciplines. (n.d.). *STEAM: A Framework for Teaching Across the Disciplines.* Retrieved November 15, 2014, from http://www.steamedu.com/

STEM to STEAM. (2016). *STEM to STEAM.* Retrieved May 10, 2016, from http://stemtosteam.org/

Tochetti, S. (2012). *DIYbiologists as "makers" of personal biologies: how MAKE Magazine and Maker Faires contribute in constituting biology as a personal technology.* Journal of Peer Production. Issue 2, Retrieved from journal: http://peerproduction.net/issues/issue-2/peer-reviewed-papers/diybiologists-as-makers/

Vanada, D. I. (2014). Practically Creative: The Role of Design Thinking as an Improved Paradigm for 21st Century Art Education. *Techne Series - Research in Sloyd Education and Craft Science A*, 21(2),21-33

Veeber , E , Syrjäläinen , E & Lind , E 2015 , *' A discussion of the necessity of craft education in the 21st century Techne Series: Research in Sloyd Education and Craft Science A,* 22(1), 15-29.

Warschauer, M. (2004). Technology and Social Inclusion. Cambridge: MIT Press.

Wright, N., & Davis, R. (2014). Educating the creative citizen: design education programs in the knowledge economy. *Techne Series: Research in Sloyd Education and Craft Science A*, 21(1), 42-61.

Tomi Dufva is a doctoral student at Aalto-University, the school of Arts, Design and Architecture, a visual art educator and artist working primarily within new media. The author is also the co-founder of art & craft school Robotti, which combines science and art education. The primary research revolves around the topics of code literacy, media literacy, critical pedagogy, issues in AI (Artificial Intelligence) research, Machine learning as well as digitality and art.

Publication 3

Dufva, T. & Dufva, M. Grasping the future of digital society'. [Article under review for Futures, The Journal of Policy, Planning and Futures Studies]. 2017

GRASPING THE FUTURE OF THE DIGITAL SOCIETY

Tomi Dufva[a]

[a] *Corresponding author*, Aalto University School of Arts, Design and Architecture, Helsinki, Finland.

Authors address: Puutarhakatu 8 A c 61, 20100 Turku, email: tomi.dufva@aalto.fi

Mikko Dufva[b]

[b] VTT Technical Research Centre of Finland Ltd., Finland, email: Mikko.Dufva@vtt.fi

Abstract

Society is increasingly digitalised and connected, with computers and algorithms mediating much of the daily actions of people in one way or another. The degree of digitalization and its consequences are challenging to understand because most people lack a first-hand experience of what digitalization actually feels like. Digitalization is abstract and difficult to grasp, which leads to a detached sense of digital surroundings. In this paper, we argue that in order to grasp the nature and future of a digitalized society, an embodied understanding of digitalization is needed. We use the concept of 'digi-grasping' to analyse our awareness and involvement in the digital world. By digi-grasping we mean active sense-making and existing in the world that consists of both a digital and a physical world. We argue that through 'grasping' the digital world it is possible to create an ethical and aesthetic attachment to society. Digi-grasping can empower people to understand and question the choices and motivations behind current digital structures and create new structures. It is thus an important approach to shaping the futures of digital society. We illustrate the concept with examples representing different modes of being and doing in the interface of digital and physical.

Key words: *digitalization, digital society, experiential foresight, craft education, art education, artistic research, embodied learning, critical theory.*

1. Introduction

Digital technologies have become ubiquitous and part of everyday life. Things that would have been regarded as science fiction just a few decades ago are taken for gran-

ted, such as modern smart phones, global information networks or virtual reality. At the same time societies are becoming ever more dependent on digital technologies and infrastructure. Banking, electrical grid management, health records, and other personal information are increasingly relying on digital networks and databases. The trend is towards even wider use of digital technologies with a lot of hype around artificial intelligence and the promise of an infinitely growing and efficient digital economy.

The switch to digital has created a significant change in technologies by introducing a 'meta layer' of code. Digital technologies rely on code that can be altered, updated, fixed, hacked, stored, and analyzed without changing the physical machine itself (Berry, 2016; Ceruzzi, 2012). The programmable and reprogrammable nature of digital technologies, as well as the possibility to gather and analyze data, instils more agency into the digital technology. Furthermore, the flexibility and adaptability of code connects humans more closely to machines, creating new forms of aggregates between human and nonhuman actors (Berry, 2016).

Digital technologies are entangled in the structures of society in many different, complex, and even contradictory ways. The information society could even be seen as a society that is dependent on the computation of information, emphasizing the role digital technologies have in society (Berry, 2016). Furthermore, Berry notes that the move to a computational information society can be seen as a shift from the previous digital era to a new post-digital world 'in which the digital has become completely bound up with and constitutive of everyday life and the so-called digital economy' (Berry, 2014, p. 15).

There has also been a lot of debate over data privacy, security, and ownership (Berry, 2016; Gangadharan & Eubanks, 2015). Attacks on different parts of the information network, from company-owned servers full of customers' personal information to domain name servers critical for the functioning of the network, show the new weak points and risks of the digital age. Companies utilising digital networks and platform thinking are disrupting existing industries. Digital tools also offer new opportunities for organising grass-root level action and thus challenge existing public decision-making structures.

In sum, there is a growing need to understand what digitalization – the umbrella term for the trend and impacts of the increasing use of digital technologies – means, if one wants to be an empowered member of the digital society. However, the degree of digitalization and its consequences are challenging to understand because most people lack - or ignore - a first-hand experience of what digitalization actually feels like. Digitalization is abstract and difficult to grasp, which leads to a detached sense of digital surroundings. But since digitalization is not going anywhere, knowing how to be and how to act in the digital world, a well as how to perceive it, become necessary societal skills. Furthermore, how the digital world is perceived (e.g. as given vs. something

that is produced and thus can be shaped) determines what kinds of futures are possible.

In this paper, we argue that in order to grasp the nature and future of a digitalized society, an embodied understanding of digitalization is needed. One way to achieve this is through approaching coding and the manipulation of the digital world through the concept of 'digi-grasping'. Digi-grasping is active, embodied sense-making and existing in the interface between the digital and physical world. We argue that by paying more attention to the modes of being and ways of acting in the digital world, it is possible to create a stronger ethical and aesthetic connection between the digital technologies and society. Digi-grasping can empower people to understand and question the choices and motivations behind current digital structures and to create new structures. For this reason, we argue that digi-grasping is an important approach to shaping the futures of digital society.

In the next section, we define the key terms used in the paper and elaborate the theoretical basis for digi-grasping. We then give some examples of exploring the in-between of the digital and the physical, drawing especially from the domains of art and activism. We use the examples to illustrate different modes of being and doing in the digital world. In the discussion section we position the findings in relation to the overall trend of digitalization and suggest digi-grasping as a key capability in the present digitalised world and in reclaiming digitality and empowering the shaping of futures of digital society. We conclude with a summary and suggestions for further research.

2. Theoretical underpinnings

The terms used to describe the phenomena of and impacts around digitalization and the diffusion of digital technologies are often vague and ambiguous. It is thus worth defining the concepts around the 'digital' and making a distinction between the digital as an aspect of a thing or technology, digitalization as a phenomenon or trend, and digitality as a condition of the digital world. In this paper, we take a broad view of what is meant by the digital and consider not only the technological or theoretical aspects but also the societal, cultural, and political aspects (Dufva & Dufva, 2016; Williamson, 2015; Vaden, 2005).

The term 'digital' has its origins in the Latin word digitalis and refers to digits. Digitality is something that is discreet in contrast of being continuous. In information technology, the term *digital* refers to the binary number system, which was adopted in the mid-20th century as a primary logic for digital computers (Ceruzzi, 2012; Steiner, 2013). The binary system and the logical framework built on top of it also entailed the ability to reprogram and update the machine without physically changing it, which

could be seen as one of the most significant breakthroughs and characteristics of digital machines (Ceruzzi, 2012).

By digitalization we refer to the actions of transforming various previously physical or analogue actions into digital data systems. The progress in digitalization has led to extensive and diverse speculation about the future of society and culture. Digitalization – often very loosely defined – is commonly referred to as one of the megatrends shaping futures.

Digitalization is a key motivation for the concept of digitality. Negroponte wrote in his 1995 book 'Being Digital' that the *'change from atoms to bits is irrevocable and unstoppable'* (Negroponte, 2015), arguing that everything that can be digitized will be digitized. Negroponte defined digitality as a concept referring to living in digital and digitized culture (Negroponte, 2015). Digitality thus refers not just to the philosophical-mathematical system nor to the fundamental technological aspects built on top of a binary structure, but also to the effects digital technologies have on our society. These issues are often intertwined with technological inventions but are not always as a direct consequence of them. For example, the rapid development of the internet caused many theorists to proclaim that the internet would democratize our society in unforeseen ways (Dreyfus, 2008; Morozov, 2014; Negroponte, 2015; Rushkoff, 2010). Another, related example is how digital technologies enabled the gathering and transcoding of various signals into one universal digital signal now widely referred to as data. One digital system can be used to represent images, sound, motion, text, etc - it is all just data. Moreover, thanks to the internet it is possible to freely distribute and copy data without loss of quality and (almost) without cost (Dreyfus, 2008; Negroponte, 2015; Petzold, 1999). Thus, digitality can be seen as a more cultural and societal way of looking at the phenomena related to the 'digital'.

In popular culture, these thoughts are echoed all the way from Gibson's 'Neuromancer' (Gibson, 1984) to Star Trek's visions of teleportation and holodecks. A great deal of post-humanist discourse has tackled digitalization - the trend towards the increasing use of digital technologies - from various aspects, ranging from AI (artificial intelligence) researcher Hans Moravec's and futurist Ray Kurzweil's theories of downloading our consciousness onto a computer as a way to save humanity (Moravec, 1988, 1997; Kurzweil, 2005) to Katherine Hayles and Donna Haraway's more embodied arguments of digitality (Hayles, 2001; Haraway, 2013). These theories challenge each other in terms of the comprehension and interpretation of the nature of digitality; digitality is considered as a place where being is possible and the body is a mere vessel. Furthermore, these distinct lines of thought extend further, to the comprehension of being, where we ask should being be understood from the Cartesian dualistic standpoint, as the separateness of mind from the body, or can humans be seen as *embodied beings*, as Haraway suggests. In other words, is being a human binary or not (Guillaume & Hughes, 2011).

One possibility to understand these speculations is through seven metaphors (machine, organism, brain, flux & transformation, culture, political system, psychic prison, instrument of domination, and carnival) based on four paradigms from social science (functional, interpretive, emancipatory, and postmodern), all highlighting different interpretations of code (Dufva & Dufva, 2016). Digitality can be seen as the larger context for code and thus might benefit from the same kind of analysis. For example, digitalization is often perceived as a functional concept: an unproblematic key to future growth (Ailisto, Collin, Juhanko, & Mäntylä, 2016). However, digitalization is also tied to intricate questions of equality, power, politics, culture, etc. In sum, the definitions of digital, digitalization, and digitality are often ambivalent and unclear. In this article, our notion of the digital world refers to this convoluted and multifaceted nature of digitality.

Although rational and explicit analysis of the concepts of the digital, digitality, and digitalization can be useful, it is not feasible in day-to-day life. Comprehending digital technologies through metaphors can be time consuming and difficult, or at the least, impractical in situations such as using digital payments at the cash register or cursing the slow internet in the supermarket. Therefore, an internalized, embodied understanding of digitality is needed to help guide us through the everyday digital structures that humans inhabit. However, to move towards this understanding, we first have to define what is meant by embodied knowledge.

2.1 Embodied knowledge

In defining embodied knowledge, we refer to research that is based mostly on phenomenology. According to phenomenology, the way humans exist in this world is through bodies, and thus humans are restricted to a subjective view of our situated bodies (Husserl, 2013). This embodiment is often thought to contradict or be separate from digitality (Dreyfus, 2008; Kim, 2001; Negroponte, 2015).

Embodiment has a double sense, as pointed out by both Merleau-Ponty and later Varela: '[I]t encompasses both the body as a lived, experiential structure and the body as the context or milieu of cognitive mechanisms' (Rosch, Thompson, & Varela, 1992 p. xvi; Merleau-Ponty, 2014). This notion highlights a crucial point: The body is an active participant not only as a place for our senses but also as a place where knowledge is formed. Craft researcher Kojonkoski-Rännäli emphasizes Heidegger's notion that, since humans are active bodily beings, existing in the world is realized through making, through doing-by-hand (Kojonkoski-Rännäli, 1995).

Merleau-Ponty uses the term *grasping* to point to an activity that is intentional but not necessarily conscious. It is possible to grasp something before knowing it; through the body, humans comprehend not only the spatiality of position but the spatiality of the

situation (Merleau-Ponty, 2014). The relevance of grasping is in how it creates and shapes the knowledge of the experienced world through the body and embodied action. The body plays an important part in knowledge creation and creates knowledge that would be hard to gather otherwise (Merleau-Ponty, 2014; Dreyfus, 2004).

The importance of embodied knowledge is that through several overlapping research strands like phenomenology, cognitive science, and especially embodied cognitive theory and enactivist theory, it shows how the mind cannot be seen as separate from body or bodily experience (Lakoff, 2013), how mind is built in interaction with the environment (Rosch et al., 1992) and how mind can be seen to be situated in the whole body (Noe, 2003, 2004).

By considering embodied knowledge in the context of digitality, we want to highlight the complex and ambiguous position that digital technologies have in everyday life. Embodied knowledge highlights how, as regards humans, digitality can be understood through being and doing in the interface between the digital and physical. It thus accentuates the complicated relationship between the body and digitality. As stated earlier, digitality is ubiquitous, and it pervades many (if not all) layers of being in modern societies. At the same time, the digital is invisible: humans are often not aware of the systems, their characteristics, their purpose, or the assumptions built into them, nor how these systems shape their behaviour. Dreyfus calls for the need to be clear about these processes:

'*not only are we transformed by the way we use our tools; we are not aware of how we are being transformed, so we need all the more to try to make explicit what the Net is doing for us and what it is doing to us in the process.' (H. L. Dreyfus, 2008 p.137.)*

2.2. Digi-grasping

In this article, we use digi-grasping as a concept through which we can describe and analyse our awareness and involvement in the digital world. In our definition, digi-grasping has different modes of manifestation, but in general, digi-grasping can be formulated as active and empowered sense-making and participation in an increasingly digitalized world that is not based on simply rational understanding, but on embodied understanding as well. It is worth noting that digi-grasping does not aim to define being in a virtual space, but is more interested in the physical world that is increasingly digitized.

In digitality, the notion of the body and embodiment are more contested: In fact, the body can even be denigrated to the level of merely 'meat', as in Gibson's Neuromancer (Gibson, 1984). Dreyfus points out that the downplaying of the body is nothing new and has happened before in western civilization: through platonic philosophy and later through Christianity. He advises us to resist this temptation because to Dreyfus, the body offers a rich environment for knowledge-making and so denying it would be

foolish: *'...without our bodies, as Nietzsche saw, we would literally be nothing. As Nietzsche has Zarathustra say: 'I want to speak to the despisers of the body. I would not have them learn and teach differently, but merely say farewell to their own bodies – and thus become silent."* (Dreyfus, 2008 *p.143-144)*

Dreyfus mostly refers to the problematics of the body in virtual reality and in manipulating digital objects, rather than addressing directly the amalgam of the physical and digital. But the underlying gist is the same: Embodiment is not only important for knowledge creation but is crucial to our being. How then to define the embodied presence within digitality?

Berry points out that in the post-digital world, digital technologies are deeply intertwined with human activities. Furthermore, Berry points out that these digital technologies should not be looked at as objects or end points of human actions, but as actors in constant communication with each other: non-human and human. Berry calls this constant stream of data 'everyday computational' (Berry, 2016). This ongoing interaction between humans and non-humans and the digital and physical is also a key aspect of digi-grasping, since it emphasises the prevalence of digitality in our daily lives.

As mentioned earlier, Heidegger saw humans as actively bodily beings that shape our world through making (Heidegger, 1952). Kojonkoski-Rännäli has expanded on this notion and argues that through making by hand, we craft intentional, emphatic, and aesthetical connection to the world around us (Kojonkoski-Rännäli, 1995, 2014). In this context, digi-grasping is used to define such making, sense-making, and existing in the world as consisting of both the digital and physical.

This two-sided being and sense-making also refers to ideas about grasping. Merleau-Ponty defined grasping both as knowledge that precedes rational knowledge and as one's comprehension of the spatiality of both position and situation. This sense-making without rational knowing as well as the comprehension of one's position and situation are substantial in digi-grasping: Through it, digi-grasping defines skills that cannot be measured in terms of the more common digital talents, such as code skills, software skills, electronic skills. Digi-grasping can thus be used to express such knowledge of digital being that would otherwise be hard to quantify or make visible. We will later describe this knowledge more accurately through examples and as different modes of being and doing in the interface between the digital and physical.

2.3. Embodiment and digitality

Digitality in itself, as an abstract and invisible concept, challenges and questions the possibility of embodiment in digitality. Ella Brians considers the whole dualistic post-human debate in her article on 'Deleuze and the body.' Do we see ourselves as minds that can be uploaded or digitality as part of the flesh? (Guillaume & Hughes, 2011). Both would allow for the individual to be free or to choose their own body.

Even if we leave the more future-oriented fantasies aside, the problem of digital embodiment remains essential. Dreyfus brings forward the risk-free aspect of digitality: Physicality and presence bring with them the risk of being vulnerable, which is not part of the digital experience. Thus, a digitally connected world is not one that has truly come together because there is no commitment and action (Dreyfus, 2008). In a similar manner, Turkle suggests that digitality breaks physical interconnectedness and leaves us alone in our body-experiential world (Turkle, 2011).

Digitality also influences everyday actions. For example, Claire Bishop has questioned the use of digital devices in art making. Are we repeating practices from the 'analogous world' in the digital world, and not rethinking them for the digital world (Bishop, 2012)? In this way the physical, embodied being bends because of digitality.

The idea behind using the concept of digi-grasping is that it acknowledges both the digital and the embodied being. Digi-grasping can be understood as being and knowing in the space and interface between the digital and physical. It not only limits to considering just the aspect of being in the digital, or the use of the digital, but also deals with the ubiquitousness of the digital. Thereby it can answer or be used to respond to the challenges of digitality.

3. Highlighting different aspect of being in the digital–physical world: five examples

As mentioned earlier digi-grasping is used to describe the understanding of the world where digital technologies are ubiquitous. Thus digi-grasping not only reflects the competences related to digital technologies and neither is it merely a term to detail a theoretical understanding of digitality. Digi-grasping includes many of the qualities of both skills and a conceptual understanding of the digital, yet it also, as the name implies, emphasizes grasping – an embodied understanding and empowered agency – of digital phenomena.

In this chapter, we present five examples of the interaction between the physical and digital world. Each of the examples is meant to introduce distinct qualities of digi-grasping so as to clarify the concept further. Our goal here is not to provide an exhaustive list of all the ways of being and doing in the boundary between the physical and digital, but rather to demystify and illustrate what digi-grasping can mean in practice. In the following chapter, we categorize the examples into different modes of being and doing in the digital world.

3.1. A drawing bot and an artist drawing together.

How to make the boundary and differences between the physical and digital visible? This is the key question from the point of view of digi-grasping in the first example: an art performance that explores what happens when a drawing bot and a human draw together. The performance consists of a drawing bot and an artist drawing on the same surface and mimicking each other. The drawing bot is a simple digital machine that, by means of motors and wheels, carries a pen across the drawing surface. The bot has a simple sensor system that is used to detect things near it. It can be programmed to avoid collision with the artist's drawing on the same surface, or it can be programmed to do something else.

illustration 1

Concerning digi-grasping, the drawbot, which is a digital device in the analog domain, brings out the differences between the digital and physical, not by explicitly stating them, but through experiencing the performance. For example, we can experience the actions of the robot and its presence, which can feel familiar but also distant. The key is not to completely understand the workings of the digital machine, nor the communication with it, but the awareness of the digital in the physical space.

The example of a drawing bot conceptualizes the differences in the digital and physical modes of being. This conceptualisation – through experience – may help us in becoming more aware of other 'bots' in the physical environment, and their relation to it. Art can thus be a substantial vehicle to bring forth questions that could not be otherwi-

se articulated (Noe, 2015). Similar articulation and awareness raising can also be done through different kinds of robotic systems, which are becoming more commonplace in education and hobbies thanks to things like the maker movement.

3.2. Adnauseam: Raising questions about the explicated digital world

The second example is a browser plugin called Adnauseam (www.adnauseam.io) developed to protect people against tracking and surveillance. Adnauseam does this by obfuscating user data (Howe, 2015). The premise is simple: The plugin hides ads on websites you are viewing, similar to common adblockers, but rather than just hiding the ads, Adnauseam-plugin also clicks all the links on the visited web page provided by the ad platform. By doing this, the plugin creates a plethora of data that is useless to the tracking services, since the aim of tracking is, after all, to categorize the user and her data. The goal of the project is not to go against advertising per se, but rather to raise awareness regarding tracking, surveillance, and privacy in the digital realm.

Adnauseam sees the web browser as one of the primary ways we interact with contemporary society. As such, the browser represents a key tool for disobedience in society (Howe, 2015). From the point of digi-grasping, Adnauseam is an example of a raised state of awareness of the digitalized world and a playful – as opposed to oppressed – attitude towards it. Adnauseam takes a stance regarding people's citizen's rights and questions the constructions of the digital world. It uses increased awareness of both the workings and impact of digital technology – understanding how and why ad platforms gather data – to question and disrupt the invisible mechanisms of tracking. It is not necessary to explicitly understand the technical details of tracking to grasp the bigger picture that Adnauseam is challenging.

3.3. I'm getting arrested: Questioning or redefining the relationship between the digital and physical.

The third example is a smartphone app 'I'm Getting Arrested' ('I'm Getting Arrested,' 2016), the concept of which is straightforward: If you are getting arrested in a demonstration, you can quickly open the app and send a preformatted text message at once to multiple people, for example, to friends, lawyers or journalists. The idea originates from the Occupy Wall Street movement and has since been extended to other similar demonstrations where police action may be questionable.

The *I'm Getting Arrested*-app is an example of how digital technology can increase agency or nudge power structures in the physical world. Here the advantages of digital technology, as well as its ubiquitousness, are used to promote one's objectives in the physical world. Digital technology is used as a means to achieve something in the

physical world that challenges existing power structures. If compared to the previous example of Adnauseam, the *I'm Getting Arrested* example redefines the relationship between the digital and physical from the physical point of view. Relevant in this example is that one is not just aware and critical towards digitality, but sees it as a possibility for action, for example, by acquiring new forms of agency in the digitalized world.

3.4. Platform cooperatives: Using the digital world to create change in the physical world.

Whereas previous examples have embodied raising awareness and questioning the structures and mechanisms of the digital world, the last two examples emphasise transformation and creativity. The examples of platform cooperatives and creative coding show how, by grasping digitality, we can use it as an agent for change or as a tool for expression.

Platform cooperatives are an ideological, political, and economic alternative to platform capitalism or the sharing economy (Scholz, 2014). Platform cooperatives differ from well-known platform companies like Uber or Airbnb in their ownership structure as well as in their mechanisms for distributing value. Whereas companies such as Uber operate according to conventional corporate principles and aggregate value to their shareholders, platform cooperatives are communal projects where the platform is created in cooperation with the workers, developers, and designers ('Platform Cooperativism - P2P Foundation,' 2015). The value captured and created by the platform is shared directly back to those who have also contributed to the platform.

Many platform companies operating under the umbrella term of the sharing economy are critiqued for the way they exploit their workers. In the case of Uber, for example, it is argued that the drivers are only users of the platform provided by Uber, not its employees. By offering a platform, Uber is freed from social and healthcare responsibilities and at the same time given a dictator-like ownership of their product (Bercovici, 2014; Stallman, 2014). A cooperative alternative for Uber, for example, could be a worker-owned platform that takes care of its drivers and benefits the workers and the app creators equally. Such cooperatives are starting to emerge as a response to the critique of Uber (e.g. the GreenTaxi cooperative).

From the perspective of digi-grasping, platform cooperatives demonstrate an awareness and questioning of the impacts of digitalization, but also an active intention to transform existing structures. As platform cooperatives seek to democratize digital economic models, such as the sharing economy, they at the same time use digitality to change the structures of the economic system and create change in society. It might not be explicitly clear what the new system will be or how it will function, but there is a feeling, an embodied vision of what direction to go.

Where platform cooperatives emphasize the structural changes in political and economic structures, creative coding accentuates the digital as a creative asset. Creative coding could be described as computer programming where the aim is not in functionality but expression (PBS, 2013). Creative coding can also be seen as a postmodern way of commenting on the digital culture (Dufva & Dufva, 2016). The important aspect in creative coding is that it uses digital technology as a medium: It can be utilized as a tool or even as artistic material for expression. Creative coding projects can be political or simply aesthetic, but in any case, they blend the physical and digital together in imaginative ways.

Lauren McCarthy's Follower is a good example of creative coding. The follower is a web service where you can request a follower for yourself. If you are chosen, the service provides a physical follower that follows you for a day by means of location data from your phone. By means of Follower, McCarthy wants to raise questions about attention and surveillance, as well as the relationship and meaning in and between them (McCarthy, 2016).

Creative coding highlights the concept of craft and doing-by-hand in the digital world. *Making* is one of the core components of existing in the world. Thus, intentional making, doing-by-hand, not only produces an artifact but also constructs a connection between the maker and the world she/he belongs to (Heidegger, 1952; Kojonkoski-Rännäli, 1995, 2014). Making is not just an activity to create an object, but an active participation in and tending to the world. We argue that creative coding is one example of making in the digital world, which can bring about an aesthetic and ethical relationship with it.

4. Being and doing in the digital world

The previous examples above demonstrate the variety of connections that humans have with the digital world. Basically, digitality can be seen as a ubiquitous presence in everyday life. Digitality both affects human beings as well as gives them new abilities for expression and for shaping society. Moreover, the relationship and interface between the physical and digital is malleable and affected by cultural, and by political, and ideological drivers and trends.

As digitality has its origins in technology, a common assumption can be that particular knowledge is required to comment on digitality. The aim of digi-grasping is to show how digitality can be embodied and grasped without a thorough, explicit, and rational understanding of the technology. Furthermore, digi-grasping highlights how this embodied knowledge of digitality can be a source of empowerment and transformation. In this section, we describe how digi-grasping appears in different modes of being and

doing in the interface between the digital and physical. These modes aim to demonstrate the awareness of the digital domain: As mentioned earlier, digi-grasping is not a measure of the rational knowledge of digitality but rather a concept for thinking and analysing the embodied experience of digitality.

4.1. The everyday mystery of the digital world

The first mode of being describes a sort of ignorance towards the digital: Being and doing in the digital world is simultaneously taken for granted and not acknowledged. Digital technologies are seen as uncomplicated and something one can or must use in modern society. The utilisation of and interaction with digital devices and software are done without an awareness of the influence of the digital technologies. Such use can be fluent and effortless or annoying and forced, but the use of digital devices happens without a grasp of the digital infrastructure and systems around the digitality, let alone their influence on behaviour.

The ignorant mode of being in the digital world highlights various irritations and frustrations that digitality can present in daily lives: the video projector refuses to show the image even though it just did, the website is not loading, and the smart house with all the internet connected devices becomes a modern-day equivalent of a haunted house. It also brings attention to the ignorance of larger issues: the collection and sharing of personal information without the person knowing or the inability to change or even comment on hard-to-use systems.

An important thing to notice is that technical knowledge in itself does not necessarily bring more awareness of the impacts of digitality, even though it can help in alleviating the ‘mystery’ around it. Rather, an embodied understanding of the underlying structures and dynamics of digital technologies – how they are connected and influence all kinds of aspects of our lives – is needed to break the ignorance.

4.2. Awareness of the digital world

The second mode of being demonstrates becoming aware of the surrounding and permeating digitality: being conscious of the presence of digitality in daily lives as well as an awareness of one's presence in the digitality. This awareness creates a feeling of interrelation with the digital world. It is not so much a question of intellectual knowing but rather about embodied experience of how digitality permeates daily life. It could be difficult or even impossible to articulate or explicate the feeling of being and doing in the interface between the digital and physical, but such articulation is not needed to grasp how digital technologies and digitalization affect, in general, everyday life and being.

The drawing performance with a robot described in the earlier section is an example of creating a visual presentation of being and doing in the interface between the digital

and physical. Interacting in a creative setting with a simple robot can raise awareness of the interfaces humans share with the digital. The awareness may manifest itself in diverse ways: It is easy to humanize the robot and start to think of it in human terms, but it might also highlight how humans unintentionally adapt themselves to the needs of the digital technologies by becoming more like robots. The performance thus may raise questions about the various modes of being between human existence and machine existence. The performance also exemplifies one aspect of digi-grasping: that awareness can emerge through experiencing and feeling without being able to articulate the relationship between the digital and physical explicitly.

4.3. Empowered being

The third mode of being goes beyond awareness and shifts the focus from how things are to how they could be. The ability to grasp digitality enables one to outline and question the relationship with the digital world. What is the interface between physical being and digital being? Why is it the way it is? Could it be different? Kojonkoski-Rännäli proposes that intentional activity in the context of crafts creates not only knowledge but an ethical bond between the actor and the world (Kojonkoski-Rännäli, 1995). Similarly, we argue that intentional being in the digital can create comparable ties in the context of digitality. Intentional awareness enables the questioning of moral issues as well as creates a feeling of responsibility for the consequences of digitalization. This process of questioning and taking responsibility can lead to alternative images of preferred futures of digital society.

The two examples presented in the previous section, the *Adnauseam*-plugin and the *I'm Getting Arrested*-app, both convey the ethical bond between the digital and the physical. The *Adnauseam*-plugin shows how raised awareness of the digital enables a questioning of how algorithms shape the user experience and ultimately creates an ethical responsibility to the digital world. Although the *Adnauseam*-plugin could be analyzed as an answer to a problem, it does at the same time convey a more embodied understanding and moral concern of the digital world. Since what one views or clicks online – the digital fingerprint – is valuable information and represents how one is defined by algorithms in the digital world, it is something that needs to be brought into discussion and reclaimed by users.

The *I'm Getting Arrested*-app instead demonstrates how the digital world can be utilised to shape the physical world. From the digi-grasping standpoint, it can be seen as extending being in the digital realm: the feeling that digitality is something that belongs to being human and that it can be used to improve life. *I'm Getting Arrested* could be seen as redefining the interface between the physical and digital by extending the interface into both directions.

The third mode of being manifests agency in the in-between of the digital and physical. Intentional awareness and challenging the existing or given assumptions of digital technologies enables a more empowered participation in modern society. This empowerment then has the ability to extend and transform both the digital and physical domains of being and eventually shape the development trajectories and lead to futures different from the current dominant vision.

4.4. Transformation and aesthetics

The fourth mode describes how through increased awareness and questioning, it is possible to reclaim agency in the interfaces between the physical and digital and to shape the direction of future developments. Whereas questioning in the third mode brought ethical dimensions into digitality, intentional creation adds aesthetic qualities to it. The questions relating to digitalization and the adoption of digital technologies are not merely moral or political. The digital world is a space in which humans spend increasing amounts of time and thus are associated with aesthetic values as well.

The last two examples in the previous section portrayed two distinct aspects of creativity in the digital domain. Platform cooperatives focus on the transformational possibilities of digitalization, while creative coding pointed to the use of digital technologies as tools and to digitality as a medium and material in artistic expression. Platform cooperatives can be seen to directly deal with the construction of futures through rethinking economic structures. By aiming to democratize the digital economy and transform the ways in which the economy works in a digitalized world, platform cooperatives can be argued to have an intentional agenda (‘Platform Cooperativism - P2P Foundation,’ 2015). From the digi-grasping perspective, platform cooperatives could be seen as – to loan a term from Heidegger – *tend to* the digital world (Heidegger, 1952). In other words, the existence and impacts of digital technologies and digitalization is acknowledged and cared for.

Creative coding in contrast uses the foundations of digitality playfully and transforms them in a creative manner. Lauren McCarthy’s The Follower can be seen from the perspective of how ubiquitous digitality is grasped and used in imaginary ways. The artwork at the same time uses digital technology and comments on it. Furthermore, it illustrates a raised awareness of digitality and portrays it as a space for creation by playing with privacy, location, and attention, all of which are important themes when discussing digitality.

The mode of creative being demonstrates how digitality can become a space filled with agency and how digitality can be playfully deconstructed and transformed. Increased awareness and experience of digitality enables an embodied understanding of and presence in the digital world. Thus, aesthetic aspects and ethical questions form an

understanding of and agency within a combined physical and digital being. This can enable reclaiming the digital world and re-imagining its futures.

5. Discussion and concluding remarks

5.1. Reclaiming digitality

The increasing digitality and digitalization of the world leads to a situation where the digital technologies and digital constructs are profoundly embedded in our daily lives. In this paper, we have suggested that to better understand the reach and the scope of digitality, a more embodied understanding of digitality is needed. The necessity of embodied understanding is significant for empowered participation in society and for shaping futures. The embodied understanding refers not only to the theoretical knowledge of digital technologies but also to the grasp of digitalization as a phenomenon. Digi-grasping highlights the embodied aspect of understanding and can be used for structuring and imagining different ways of doing and being in the interface between the digital and physical.

As society becomes evermore digitalised and enters into a post-digital era where lives are ultimately bound up with the digital, as suggested by Berry (Berry, 2014, 2016), the question becomes who sets the direction of the advance of society? Alternatively, who is capable of setting the direction, even? One of the premises of this article is the notion that as abstract phenomena, digital technologies are difficult to understand. When this intangible nature of digitality is combined with the increasing demand for productivity through innovative digital technology, the imbalance of interests between the dominant players – most of them corporations – and society at large becomes evident. For example, many digital technology companies entertain an overly optimistic faith towards the progress of digital technologies. This belief in the natural progress of digital technology to solve pressing problems often bypasses the societal, political, and cultural aspects and opinions of the future of digitality (Dyson et al., 2009; Koponen, 2010; König et al., 1985; Wajcman, 2014). Understanding digitality through concepts such as digi-grasping can help to reclaim the discussion of digitality for society and democratic or even grassroots policy making. Furthermore, raising awareness of digitality can lead to more critical and balanced views of digital technologies, which can then create a space in which to question the dominant deterministic rhetoric of digital technologies.

5.2. Disrupting disruption

One of the characteristics of digitalization, especially in the post-digital era, is its disruptive quality. From (illegal) file sharing (e.g. Napster and BitTorrent) and iTunes to

current streaming services like Spotify and Netflix, digitalization continues to disrupt media industries. The sharing economy persists in the shape of finding new economies to replace with digital versions: Airbnb is disrupting the hotel industry, and Uber has taken on traditional taxi services. Moreover, recent advances in artificial intelligence, mostly in machine learning, is expected to disrupt even more industries (Makridakis, 2017).

Rushkoff points out that even though many traditional industries have been replaced with digital copies, the underlying model of the economy has not changed. For example, Uber still looks after the interests of its shareholders. Furthermore, Rushkoff argues that all the disruption has simply taken neoliberal capitalism to its extreme: We are doubling down on the industrial age mandate of growth above all (Rushkoff, 2016). However, from the futures standpoint, one could see the disruption as an open window for change. The question is therefore which direction to go. For example, platform cooperatives are a way of rethinking the economy and the distribution of value, while the current digital economy has been a hyped-up version of the old, as Rushkoff stated. Becoming aware of the influence and impact of digital technologies and digitalization could bring about more democratic directions for digitality.

5.3. Grasping

As Kojonkoski-Rännäli states, making by hand is at the core of being human. Through making, one at the same time manifests her being as well as constructs ethical and aesthetic connections to the surrounding world. Furthermore, not only does making create knowledge through experience, but the world is grasped through the act of making; that is, it is understood in a way that precedes rational knowing (Heidegger, 2005; Kojonkoski-Rännäli, 1995; Merleau-Ponty, 2014). These remarks about knowledge building through making and existing in the world create a strong case for a more embodied knowledge.

However, these observations have previously been limited to discourses on the physical world. Through digi-grasping we seek to extend into the digital realm the creation and use of embodied knowledge through making. As Dreyfus and Berry (Berry, 2016; 2014; Dreyfus, 2008) state, digitality permeates our existence and sensed world in multiple and complex ways. Furthermore, Czegledy and Czegledy point out that a whole view of the human body is filtered through digital devices, whether it is measuring our heart rate or brain activity or analyzing DNA samples (Czegledy & Czegledy, 2000).

Through examples of embodied digitality and different modes of digi-grasping, we want to demonstrate the means for discussing aspects of digitality that go beyond technical or intellectual knowledge. Through being and creating in the digital domain, we attain not only knowledge, or artifact, but also moral and aesthetic connections to

the digital world. The importance of such awareness becomes increasingly significant in the post-digital era.

Media education has for a long time raised concerns about both the increased use of digital media, as well as the increased use of digital technologies (Kupiainen, 2005; Saariketo, 2015). One of the possible uses for digi-grasping could be to further structure the discussion. Through digi-grasping it becomes possible to discuss and analyze digitality in a way that does not require technological expertise. For example, attention could be brought to ignorance of digitality and awareness could be raised through experiencing digitality. Furthermore, this awareness can lead to questioning and reshaping the relation to digital world. In the same way that we train our ears to listen to certain sounds, we could train our body to grasp digitality through an explicit focus on what using digital technologies feels like. However, it is worth keeping in mind the differences between the digital and physical world: the digital world is discreet and fragmented, whereas the physical world is continuous and analogous.

Digi-grasping can extend the scope of media education into more embodied view of the digitality. Besides approaching digital technologies from the functional point of view, for example on how to use it or thinking critically about digitality, media education can use digi-grasping to help position oneself in the post-digital domain, where one exists both in a physical and digital world. Through digi-grasping and the modes of being and doing, it may be easier to grasp the reach of digitalization, or even to feel more empowered in the post-digital world.

5.4. Art as a foreshadower

In many of the examples for highlighting the various aspects of digi-grasping, we have drawn from the art domain. This is because art can offer a more embodied experience of digitality. Art can be seen as a way of creating bridges between abstract thinking and experience (Parsons, 1987; Räsänen, 2000). Alternatively, it can be seen as an essential tool for gaining an understanding of the ways humans organize themselves (Noe, 2015). From the futures standpoint, art is not only a diagnostic device of society, but can also have a role as an antenna, sensing future social, cultural, economic, and political shifts in society. Cubitt proposes that one of the core questions in thinking about future through art is the definition of the ontology to be used when everything is increasingly digital (Cubitt, 2007). Art can be seen as exploratory and nomadic. Through making art, that is through exploring and creating, one can gain an understanding of new domains, such as digitality. Furthermore, art exists in multiple domains simultaneously. It can simultaneously be local and communal, as well as abstract and global, creating messages that can foreshadow the possible societal, cultural, or technological transformations (Cubitt, 2007; N. Czegledy & Czegledy, 2000).

In our example of the drawing bot and the artist drawing together, art acts in the ways mentioned above: It highlights the structures and differences of the digital and physical and at the same time propose new ways to deal with digital technology. These ideas are not necessarily born out of rational reasoning, but through a grasped and embodied experience of the digital domain. As such, experiencing art merges the abstract into embodied experience.

Czegledy and Czegledy (2000) also point out that through digitalization the image of the body itself has been transformed. From the experience of sickness to surgery, digital technologies and digital visualization are used to present the image of the body back to oneself. In this way, an understanding of the body is already merged with the digital. Art can then be seen as a way to reclaim and comment on the embodied experience. For example, the French performance artist Orlan, who designs her body with software and surgically transforms herself into a digitally created being, has stated 'This is my body, this is my software' (Czegledy & Czegledy, 2000). These sorts of artistic endeavours exemplify embodied digitality and as such can raise awareness of the digital.

5.5. Limitations and further research

Digital technologies share a somewhat problematic relation to the body, which can be seen both in popular culture as well as in research. Nevertheless, the importance of the body and embodied knowledge should not be underestimated. Further, studies that highlight digital technologies in everyday life, in physical being, are rare. The concept of digi-grasping can be used as a theoretical construct with which to discuss digital technologies in embodied knowledge.

In this article, we have discussed the theoretical underpinnings of the concept of digi-grasping and the modes of being in the interface between the digital and the physical. This article is thus conceptual in nature and would benefit from empirical validation, as well as from more examples. Further research could thus focus on applying the concept of digi-grasping. However, it should be noted that this article draws on the practical experiences of one of the authors in the field of media and art education.

With our article, we want to highlight the complex ways in which digital technologies manifest in society. To gain a better understanding, we argue that besides rational knowledge, a more embodied knowledge of the digital, digitality, and digitalization is required. Through the embodied understanding of digitality, we want to show how digital technologies are linked and occur in everyday life and how these digital phenomena can be experienced and understood. With the use of the concept of digi-grasping, we offer a way to discuss more generally the different modes of being aware of the ubiquity of digital technologies.

References

Ailisto, H., Collin, J., Juhanko, J., & Mäntylä, M. (2016). Onko Suomi jäämässä alustatalouden junasta? Valtioneuvoston selvitys- ja tutkimustoimikunta

Bercovici, J. (2014, August 14). Uber's Ratings Terrorize Drivers And Trick Riders. Why Not Fix Them? Retrieved May 8, 2017, from https://www.forbes.com/sites/jeffbercovici/2014/08/14/what-are-we-actually-rating-when-we-rate-other-people/#6d373080ebca

Berry, D. (2016). The Philosophy of Software. London: Springer. http://doi.org/10.1057/9780230306479

Berry, D. M. (2014). Critical Theory and the Digital. A&C Black.

Bishop, C. (2012). Digital Divide: Claire Bishop on Contemporary Art and New Media.

Ceruzzi, P. E. (2012). Computing. MIT Press.

Cubitt, S. (2007). Media art futures. *Futures*, *39*(10), 1149–1158. http://doi.org/10.1016/j.futures.2007.05.001

Czegledy, N., & Czegledy, A. P. (2000). Digitized bodies, virtual spectacles. *Futures*, *32*(2), 103–120. http://doi.org/10.1016/S0016-3287(99)00070-1

Dreyfus, H. L. (2008). On the Internet, Second edition, 1–181.

Dreyfus, H. L., & Dreyfus, S. E. (2004). A phenomenology of skill acquisition as the basis for a Merleau-Pontian non-representationalist cognitive science. *Berkeley*.

Dufva, T., & Dufva, M. (2016). Metaphors of code—Structuring and broadening the discussion on teaching children to code. *Thinking Skills and Creativity*, *22*, 97–110. http://doi.org/10.1016/j.tsc.2016.09.004

Dyson, J. F., Forster, E. M., Fukuyama, F., Welin, S., Joy, B., Heilbroner, L. R., et al. (2009). Technology and Society. (G. D. Johnson & M. J. Wetmore, Eds.). The MIT Press.

Gangadharan, S. P., & Eubanks, V. (2015). Data and discrimination: Collected essays. New America

Gibson, W. (1984). Neuromancer. Ace.

Guillaume, L., & Hughes, J. (2011). Deleuze and the Body. Edinburgh University Press.

Haraway, D. (2013). Simians, Cyborgs, and Women. Routledge.

Hayles, N. K. (2001). How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Infomatics. Chicago: U of Chicago P, 1999.. Writing Machines.

Heidegger, M. (1952). Vortrage und AufsÄtze (Pfullingen) 1954. Einfürung in die Metaphysik.

Heidegger, M. (2005). Introduction to Phenomenological Research. Indiana University Press.

Howe, D. (2015). Surveillance Countermeasures_ Expressive Privacy via Obfuscation. *Aprja*.

Husserl, E. (2013). The Idea of Phenomenology. Dordrecht: Springer Science & Business Media. http://doi.org/10.1007/978-94-015-7386-3

I'm Getting Arrested. (2016). I'm Getting Arrested. Retrieved May 8, 2017, from http://www.2q2.com

Kim, J. (2001). Phenomenology of Digital-Being. *Human Studies*, *24*(1-2), 87–111. http://doi.org/10.1023/A:1010763028785

Kojonkoski-Rännäli, S. (1995). Ajatus käsissämme. Turun yliopisto, Rauman opettajankoulutuslaitos.

Kojonkoski-Rännäli, S. (2014). Käsin tekemisen filosofiaa. University of Turku.

Koponen, J. M. (2010). FutureSelf: Emerging digitized life patterns and a personal future simulation system. *Futures*, *42*(9), 981–994. http://doi.org/10.1016/j.futures.2010.08.020

König, W., Winner, L., Hughes, P. T., Schwartz Cowan, R., Cockburn, C., Bloch, M., et al. (1985). The Social Shaping of Technology. (D. MacKenzie & J. Wajcman, Eds.). Open Univeristy Press. http://doi.org/10.5771/9783845269238-268

Kupiainen, R. (2005). Mediakasvatuksen eetos. Lapin Yliopisto

Kurzweil, R. (2005). The Singularity Is Near. Penguin.

Lakoff, G. (2013). Philosophy In The Flesh, 1–590.

Makridakis, S. (2017). The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures*. http://doi.org/10.1016/j.futures.2017.03.006

McCarthy, L. (2016, January 1). Follower. Retrieved February 13, 2017, from http://lauren-mccarthy.com/Follower

Merleau-Ponty, M. (1945). Phenomenology of Perception. Routledge

Moravec, H. (1988). Mind children: The future of robot and human intelligence. Cambridge, Mass. : Harvard University Press.

Moravec, H. (1997). The Senses Have No Future, Der Sinn der Sinne International Congress [online]. Kunst und Ausstellungshalle der Bundesrepublik Deutschland, Bonn ….

Morozov, E. (2014). To Save Everything, Click Here. PublicAffairs.

Negroponte, N. (2015). Being Digital. Vintage.

Noe, A. (2003). Out of our heads. Why you are not yours Brain, and other lessons from the Biology of Consciouness. New York: Hill & Wang

Noe, A. (2004). Action in perception. The MIT press

Noe, A. (2015). Strange Tools. Hill Wang.

Parsons, M. J. (1987). How We Understand Art.

PBS, (2013). The Art of Creative Coding. pbs.org. Retrieved February 2, 2017 from:http://www.pbs.org/video/2322911761/

Petzold, C. (1999). Code: The Hidden Language of Computer Hardware and Software. Microsoft Press.

Platform Cooperativism - P2P Foundation. (2015). Platform Cooperativism - P2P Foundation. Retrieved May 7, 2017, from http://wiki.p2pfoundation.net/Platform_Cooperativism

Räsänen, M. (2000). Sillanrakentajat, Kokemuksellinen taiteen ymmärtäminen. Gummerus Kirjapaino Oy. Jyväskylä.

Rosch, E., Thompson, E., & Varela, F. J. (1992). The Embodied Mind. MIT Press.

Rushkoff, D. (2010). Program Or Be Programmed. OR Books.

Rushkoff, D. (2016). Throwing Rocks at the Google Bus. Penguin UK.

Saariketo, M. (2015). Reflections on the Question of Technology in Media Literacy Education. *Reflections on Media Education Futures*.

Scholz, T. (2014, December 5). Platform Cooperativism vs. the Sharing Economy. Retrieved May 1, 2017, from https://medium.com/@trebors/platform-cooperativism-vs-the-sharing-economy-2ea737f1b5ad

Stallman, R. M. (2014). Reasons not to use Uber. Retrieved May 8, 2017, from https://stallman.org/uber.html

Steiner, C. (2013). Automate This:. Portfolio Trade.

Turkle, S. (2011). Alone Together:. Basic Books, Inc.

Vaden, T. (2005). Digital Nominalism. Notes on the Ethics of Information Society in View of the Ontology of the Digital. *Ethics and Information Technology*, *6*(4), 223–231. http://doi.org/10.1007/s10676-005-0350-7

Wajcman, J. (2014). Pressed for Time: The Acceleration of Life in Digital Capitalism. University of Chicago Press.

Williamson, B. (2015). Political computational thinking:. *Critical Policy Studies*, 1–20. http://doi.org/10.1080/19460171.2015.1052003

Publication 4

Dufva, T. (2018) Creative Coding at the arts and crafts school Robotti (Käsityökoulu Robotti). In proceedings of Digital Humanities in the Nordic Countries 3rd Conference, Helsinki, Finland, March 7-9, 2018, CEUR-WS.org

Creative Coding at the arts and crafts school Robotti (Käsityökoulu Robotti)

Aalto-University, the school of Arts, Design and Architecture,

tomi.dufva@aalto.fi

Abstract. The increasing use of digital technologies presents a new set of challenges that, in addition to key economic and societal viewpoints, also reflect similar use in both education and culture. On the other hand, instead of being a challenge, digitalisation of our environment can also be seen as new material and a new medium for expression. This article examines creative coding both as a method for the better understanding of digital structures, and as an ability for self-expression through digital technology. The research focuses on Käsityökoulu Robotti, a type of art school for children, which offers children teaching on art and technology. Through ethnographic research, this article examines how creative coding work is employed at Käsityökoulu Robotti to promote both artistic expression and a critical understanding of technology.

Keywords: Art education, digital culture, digitality, peer learning, art +tech, education, creative coding, media education, critical thinking

1. Introduction

Digital technology is now part of everyday life. From work to leisure, the everyday tasks of sending messages to operating large infrastructures, digital technologies have replaced previous technologies and routines. Berry calls this change the post-digital era, signifying the intertwined and complex nature that digital technology now has in society (Berry 2016). Post-digital refers not to the end of a digital era or digitalisation, but to the current situation where digital technology is ubiquitous and complexly intertwined with everyday life (Berry 2015, 2016). The effects of the post-digital are also reflected in art education (Knochel & Patton 2014; Shaw & Wagelie 2016; Wang 2016) as well as children's everyday lives, as increasingly, more play and toys are becoming digitalised in some form or another. From cheap digital toys to augmented and virtual reality environments, digital technologies are now a consistent natural part of most children's habitats (McReynolds 2017; Turkle 2011).

Digital technologies differ from the previous technologies because of their programmed nature. The underlying codes present in digital technology allow a product or service to be programmed, reprogrammed, hacked, updated and analysed (Berry 2016; Ceruzzi 2012). Berry remarks that the programmable and reprogrammable nature of digital technology (code) together with the flow of processes from one digital device to another, instils agency into the digital technology itself (Berry, 2016). Further still, digital technology allows an effortless and invisible gathering of information. As such, digital technologies present questions of both power and ethics: Who decides how these products are programmed? For whom are they programmed? Who owns and benefits from the collected data? (Author 2016; Rushkoff 2010, 2016) As a recent example, Internet-connected toys can now collect children's conversations and send them to companies to be processed and analysed, awakening even more concerns about privacy on an entirely new and more serious level (McReynolds et al. 2017).

The programmable nature of digital technology demonstrates how this technology is malleable and can be seen to reflect both conscious and subliminal values of the programmer, a software company or a society's understanding of good code (Giroux 2011; Lessig 2009; Rushkoff 2010). Therefore, the ability to understand code, the underlying basis of digital technology, is a question of equality: Without comprehension of the surrounding digital structures, it becomes hard or impossible to critique or change them (Freire 2016; Rushkoff 2012). One of the challenges when responding to these questions is how to find ways to avoid a new kind of digital divide between those who understand the code and those who do not (Dufva, 2016). In that regard, this article proposes creative coding as a means of examining and understanding the

structures of the digitally mediated world. This understanding, in turn, can partially help to prevent a greater digital divide. As such, this article suggests creative coding not only as creative use of code but as a way to empower children in the post-digital era.

The intertwined and complex relationship that exists between humans and digital technology reflects both art-making and expression. In the post-digital era, using digital technologies as a way of self-expression should not be considered as a speciality, but instead as a significant medium to use to comment on the post-digital world. As with any artistic medium, creative coding offers a unique set of tools that can express views that otherwise might be difficult to communicate (Cox 2013). This article focuses on the Robotti art and craft school (Käsityökoulu Robotti), a school that provides education at the intersection of art and technology with an interest in empowering children in the digital domain (Käsityökoulu Robotti 2017). In particular, this article focuses on how Robotti applies creative coding in its teaching.

2. Creative Coding

The use of digital technologies and programming in visual arts has an extensive history. Greenberg (2007) traces it to the birth years of digital computing in the late 1950s; moreover, art and technology share an even longer history, as noted for instance by Shanken (2001). Even though digital tools, in general, have now migrated into the arts (Berry 2015; Bishop 2012), it can be argued that programming has never been mainstreamed in the art world (Cox 2013; Taylor 2014).

Creative coding is described as a type of programming where expression is more important than function (PBS 2013). This emphasis indicates a style of programming that for instance puts more emphasis on to the aesthetic values of the code, considering programming languages as poetry or treating code as an art material, rather than as a system of creating software. Generative art, a popular genre inside creative coding, takes advantage of the processing capabilities of computers to create artworks with the help of programmed autonomous systems. Here the idea of creative coding is clear: Instead of producing software, such as for instance word processing software, the programmer utilises code directly in the making of the artwork. Knochel and Patton (2015) liken creative coding to any other practice undertaken in an art studio: By learning the basics of the medium, one can start to express and even break the rules. Thus, creative coding includes learning the basics of programming, but instead of applying those techniques in a rigid, formal manner, a creative coder might seek to find an individual way, a voice, through coding. Some programming languages, programming environments, and even devices have already been built especially for creative coding (for example, processing.org, openframeworks.cc, arduino.cc, rasperrypi.org). Common to all of these is that they have transformed programming into something one can today experiment with ease. Recently, Zach Lieberman, an artist, programmer and educator released a smartphone app called "Weird Type" (2018), which gives the user the ability to write texts in space via augmented reality. This program utilises both regular programming tools and ones created for artists to produce software that is functional but could also be considered an artwork per se. Furthermore, these platforms, as well as the culture of creative coding, expand programming from the act of writing code to the creative use of digital technologies in general. Instead of just building software, many projects, like Arduino and Raspberry Pi, add electronics, sensors and interactivity to the domain of creative coding. For instance, artist Lauren McCarthy uses code along with electronics to create her artworks. These range from the more conceptual work, "Follower": a service that provides a real-life follower for a day with the help of a smartphone (McCarthy 2016) to a more concrete use of code and electronics in "Conversacube" (2011), a small electronic device that listens to conversation and aims to steer the interaction of the participants by displaying suggestions like: "complement her clothing", "touch hands" or "lean forward" on its small screen. Even though "Conversacube" is a working device, its function is to question the role of digital devices in everyday life and as such is more an art work than a commodity. The expansion of creative code from writing code to the use of digital technologies as a medium provides space for greater exploration and creative expression (Author 2016; Greenberg 2007). Cox suggests that code, like language in general, "evokes complex processes through which multiple voices can be expressed, modified, and further developed" (Cox 2013: 16). As such, the artistic use of code should be seen as a meaningful medium for commenting on the contemporary world alongside other known and long-used art mediums.

2.1 Creative Coding as pedagogy

This current research effort suggests that creative coding can be both an artistic use of code as well as a method for gaining an understanding of the surrounding digital world. These two modes are not separate, but rather intertwined with each other. Through coding, one creates art, and yet at the same time, one shapes the connection to the world being created. As such, this research suggests creative coding as a pedagogical method for raising more awareness through the act of creating in the digital realm. This article expands the art educational framework of creative coding in this research.

The primary art educational view this research takes inspiration from is experiential art interpretation (Erickson 1999; Kolb 2014; Räsänen 2000). The basis for this model is the process of using art in constructing and understanding self. Experiential art understanding combines art history, aesthetics, and critical thinking with experientially based processes of observation, conceptualisation, and production. The goal lies in comprehending the broader structures of an issue as well as developing cognitive skills. As such, experiential art interpretation is both an individual and societal emancipatory activity (Räsänen 2000). The interplay of experiential art interpretations between individual experiences and abstract concepts (Parsons 1987; Räsänen 2000), along with the ability to anchor abstract concepts to experience, becomes crucial when dealing with the digital world, which is abstract by its very nature (Author 2016; Lessig 2009; Rushkoff 2010, 2013). From this perspective, artistic use of code can be seen as a way to substantiate abstract concepts in each doer's everyday life.

In general, the main goals of post-modern art education align directly with the goals of creative coding: Critical and creative thinking, experiential learning and searching, and deconstructing culture through various perspectives, as well as inspecting culture through differ- ent sub- and micro-cultural aspects (Efland et al. 1996; Erickson & Räsänen 1999; The Finnish Association of Art Schools for Children and Young People 2013). For instance, critical thinking on the use and role of digital devices is essential in creative coding, as can be seen in for instance Lauren McCarthy's aforementioned "Follower", which wants to highlight issues of privacy, surveillance, and use of digital devices (2016).

Another significant aspect of art in relation to this research is its power to bring forth questions that might otherwise be hard or impossible to formulate, and to bring up everyday themes under particular introspection (Dissanayake 1992; Noë 2015). Dissanayake (1992) uses the term with the special meaning that art can highlight something about being human, or about society, that might not otherwise reveal itself. Similarly, Noë (2015) sees art as an activity that organises and reorganises the world. In the current post-digital world, the questions about the conditions of post-digital are substantial. The sorts of commentary, critique, and understanding of the digital world that creative coding can bring to the surface are of great importance.

Furthermore, the experiential nature of creative coding can be further inspected through phenomenology. The Finnish craft professor, Kojonkoski-Rännäli, following Heidegger, considers making by hand the basis of human existence: Making is not only a creation of an object; it is also active sense-making that relates one to the surrounding world (Heidegger 1952; Kojonkoski-Rännäli 1998). The digital world can often appear distanced and abstract (Fuller 2008). Through phenomenology, creative coding can be seen as a process that creates a tangible and embodied understanding of digital construction (Author 2017).

The notion of coding as an act of making by hand is debatable, as it does not involve a direct connection with the material, but rather a connection to an intermediary medium of code. However, it can be argued that code could be seen as the very material of digital technology; in its way, it constructs the digital world (Berry 2016; Lessig 2009; Rushkoff 2010). Moreover, many programmers identify themselves with artisans (Buechley & Perner-Wilson 2012; Cox, Mclean, & Ward 2005; Greenberg 2007). Even further, programmers can be seen, in Heideggerian terms, to "tend" the digital world, highlighting an attachment and sense of relation to the digital world. (Heidegger 1952; Kojonkoski-Rännäli 1995). For instance, the Free Software movement is not only a political and ideological movement, but it also cares for the way in which we construct the digital world (Stallman et al. 2009; Ratto 2011).

2.2 Code Literacy and Creative Code

One of the cultural aspects of creative code is its involvement in the Free/Libre and Open Source Software (FLOSS) ideologies. The general idea of FLOSS is that the ability to see how a program is built is a democratic right. Without seeing how a piece of software is written, we have no way of knowing what the software does, nor the possibility to change it (Stallman et al. 2009; Vaden 2005). Regarding creative coding, FLOSS means the ability to benefit from and build on the work of others. For example, machine learning or other sophisticated algorithms may be out of reach for the average creative user; yet, with openly usable code, anyone can benefit from using these techniques (see, for example, https://aiexperiments.withgoogle.com/).

The maker movement is a broader cultural movement that focuses on the resurgence of making by hand, coupled with an interest in the new digital technologies for production and sharing (Anderson 2012; Blikstein & Krannich 2013; Dougherty 2012; Halverson & Sheridan 2014; Hatch 2013; Martinez & Stager 2013). Creative coding shares the attraction to digital technologies as well as an interest in making by hand (Author 2017). Underlying both the maker movement and creative coding is an interest in code, digital technologies and also the world created using that code (Buechley & Perner-Wilson 2012; Cox 2013; Lang 2013).

Creative coding as a culture, as well as the maker movement and the FLOSS culture, brings out the cultural, political, economic, legislative and societal aspects of digital technologies. As a culture and practice that is closely linked to FLOSS and the maker movement, creative coding presents educators with opportunities that go well beyond the usual understanding of coding.

2.3 Other cultural perspectives related to creative coding

One of the cultural aspects of creative code is its involvement in the Free/Libre and Open Source Software (FLOSS) ideologies. The general idea of FLOSS is that the ability to see how a program is built is a democratic right. Without seeing how a piece of software is written, we have no way of knowing what the software does, nor the possibility to change it.(Stallman et al., 2009; Vaden, 2005). Regarding creative coding, FLOSS means the ability to benefit from and build on the work of others. For example, machine learning or other sophisticated algorithms may be out of reach for the average creative user; yet with openly usable code, anyone can benefit from using these techniques (See, for example, https://aiexperiments.withgoogle.com/)

The maker movement is a broader cultural movement that focuses on the resurgence of making by hand, coupled with an interest in the new digital technologies for production and sharing (Anderson, 2012; Blikstein & Krannich, 2013; Dougherty, 2012; Halverson & Sheridan, 2014; Hatch, 2013; Martinez & Stager, 2013). Creative coding shares that same attraction to digital technologies as well as an interest in making by hand (Author, 2017). Underlying both the maker movement and creative coding is an interest in code, digital technologies and also the world created using that code (Buechley & Perner-Wilson, 2012; Cox, 2013; Lang, 2013).

Creative coding as a culture, as well as the maker movement and the FLOSS-culture, bring forth the cultural, political, economic, legislative and societal aspects of digital technologies. As a culture and practice that is closely linked to FLOSS and the maker movement, creative coding presents educators with opportunities that go well beyond the usual understanding of coding.

3. Research Subject and Methods

As mentioned in the introduction, Robotti is a non-profit organisation that focuses on the fusion of art and technical education. Robotti was founded in 2012 with the objective of establishing a “child-friendly hacker space”. Currently, one of the core ideas of Robotti is to provide continuous teaching in the field of art and technology to “encourage children in creative and adventurous inquiry in the digital domain through art” (Käsityökoulu Robotti 2017).

Käsityökoulu Robotti identifies itself with the art school system in Finland. Seeking to educate children on both the artistic use of digital technologies as well as the culture surrounding it, Käsityökoulu Robotti sees itself as deviating from code school projects (for instance, code.org, in Finland koodikoulu.fi). All of the teachers at Käsityökoulu Robotti have gained

education in fields related to the arts or crafts, and many of them are art educators. Figure 1 situates Robotti in its thematic context based on the topics that were raised in interviews, questionnaires, and informal discussions during this particular research effort.

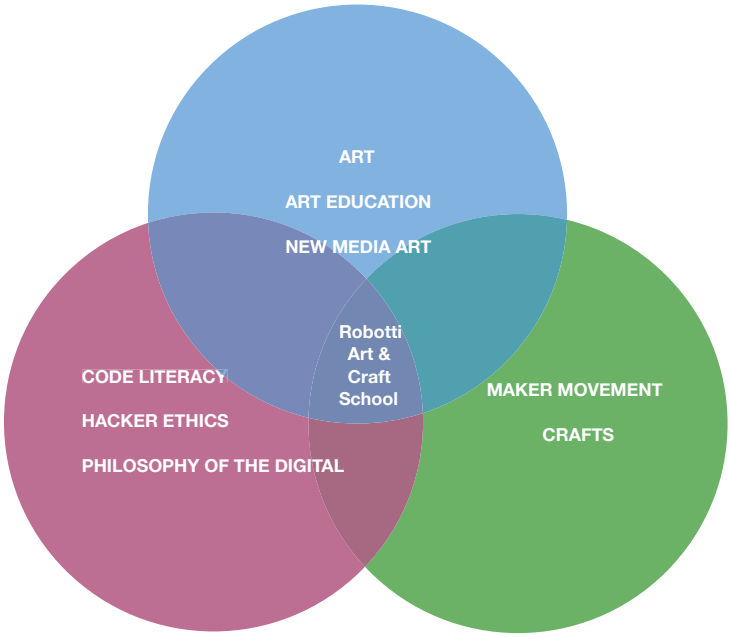


Figure 1: Situating Käsityökoulu Robotti in its thematic context. (author's work)

3.1 Research Methodology

The research into Robotti was a longitudinal ethnographic process for the five years of Robotti's existence so far. The ethnographic material consists of direct observations, as well as field notes and many informal discussions at Robotti. During the research project, questionnaires were given to students and teachers at Käsityökoulu Robotti. In the final year of the research, interviews were arranged with the central teachers at Käsityökoulu Robotti (three interviews), and an online questionnaire was given to all the teachers at Käsityökoulu Robotti. Furthermore, during the research process, several videos and photographs were shot; however, they are used only for illustrative purposes in this current article.

The results gathered from Käsityökoulu Robotti on creative coding were contrasted, and their perspective broadened, with two interviews with professors specialising in digital art education and new media. Dr. Robert Sweeney is an Art Education Professor at the Indiana University of Pennsylvania, who specialises in digital culture in art education. Dr. Ryan Patton works at the Virginia Commonwealth University as an Assistant Professor and has specialised in new media art education and created the currentLab, a new media art education research initiative (http://currentlab.art.vcu.edu). Further still, online surveys given to students and teachers taking creative coding classes at the University of Turku were gathered. Through close reading, these materials were analysed according to their relevance and perspective on creative coding. Due to the newness of the school, no clear data on the children's understanding of creative coding, nor the development of that understanding, could yet be seen. Therefore, this article only uses the questionnaires and remarks from children for illustrative purposes.

3.2 Researcher Bias

The collected materials present a historical perspective on the development of Robotti and the thinking behind its declared role. However, at the same time, the researcher acknowledges the possible subjectivity as well as biases inherent in ethnographic research (LeCompte 1987). Thus, this research offers one interpretation of the teaching at Robotti. However, this potential weakness of the research is partly compensated for by hearing the teachers both in an interview

and an anonymous questionnaire and contrasting their views with the theories presented here. Furthermore, interviews with art education professors expert in the field were added to broaden and question the perspectives.

4. Findings and Discussion

Analysis of the research materials offers a diverse picture of the teaching at Käsityökoulu Robotti. This article uses the concept of creative coding to look at the teaching used in Robotti. From this context, a shared general direction and purpose of Robotti can be seen among all the teachers there. For instance, all three interviewed teachers saw art as an essential educational method for examining digital technology. Two teachers saw art as a differentiator between Robotti and, for example, the code schools. Art was said, "to give more freedom to explore digital technologies as well as situate themselves in the digitalised world than, as a comparison, mathematics or technology education can offer them" (Interview, 17.3.2017). Even though many questions and possible pathways arose during the research project, for instance, gender issues in technology education and disability and technology, the primary question of this research project was to examine different approaches and perspectives on using creative coding as a teaching method at Robotti.

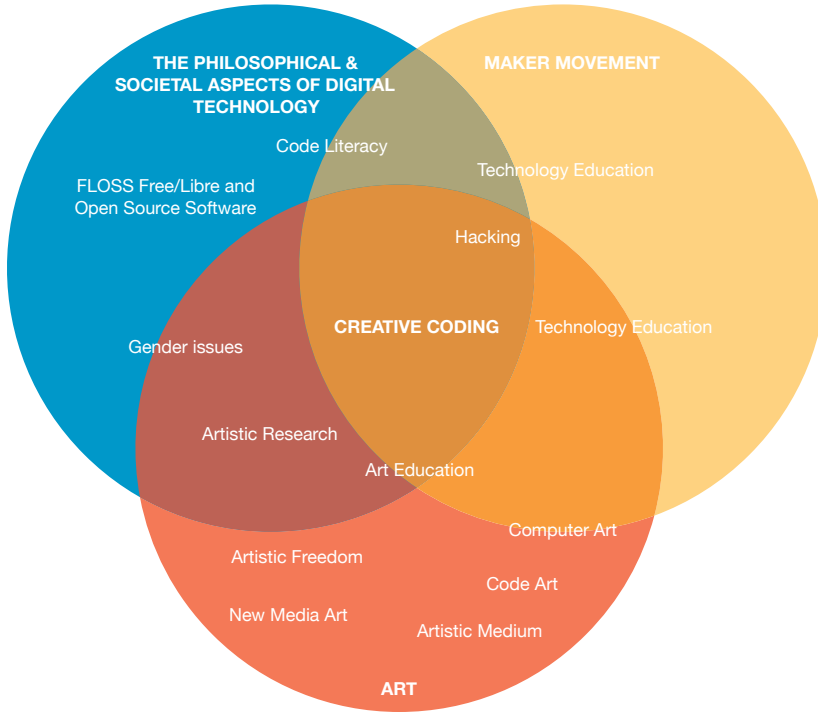


Figure 2: Situating Creative Coding in its thematic context. (author's work)

4.1 The Concept of Creative Coding

All of the teachers at Robotti are familiar with the term creative coding, although each teacher emphasises different aspects of creative coding. Creative coding can thus be seen as a way to deal with the understanding of our digitalised environment to one person, while for another person, creative coding can be perceived as more of an issue of beautiful code. Figure 2 illustrates the three top perspectives and sub-themes of creative coding that emerged through a close reading of the research material during this research project. The position of each sub-theme is displayed as it relates to the three main perspectives. For example, while the teachers

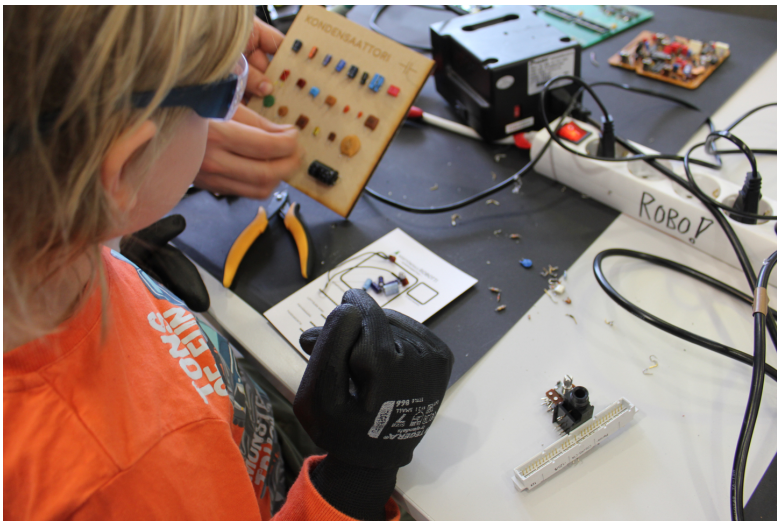
mostly talked about artistic research regarding the perspective on art, philosophical and societal aspects of that code were also present. However, the position of the sub-themes does not present the exact relationship of them to each other but instead is a way to visualise the approximate position of each sub-theme overall.

4.2 Code as a Freedom and a Right

In the philosophical and societal context, creative coding acts as a method to concretise the questions of code into the everyday lives of children as well as to address questions of code literacy and empowerment in the post-digital era (Author 2016; Morozov 2014; Rushkoff, 2010, 2013, 2016; Stallman et al. 2009). Among the teachers at Robotti, creative coding was seen as a liberating method, differing from the more rigid engineer approach and thus making it easier to deal with the ethical and societal questions related to digital technologies. One teacher described this method as a technology unchaining itself from its utility and instead emphasising the feeling of the technology. Moreover, the hands-on method of creative coding was seen to bring forth better comprehension of the digital world. In an interview, one teacher expressed this perspective as follows: "Creatively examining our coded structures can evoke a critical understanding of these surroundings" (Interview 17.3.2017). Another teacher linked their view more directly to the ideologies of Free Software (FLOSS), stating that through coding and specifically through using and altering other people's code, the importance of free software becomes easier to demonstrate and understand (Interview 6.7.2017).

4.3 Digital Handicrafting

The second perspective approaches creative coding through the maker movement, which in-



Student exploring digital components and creating his own electronic "herbarium". Photo by Roi Ruuskanen 2016.

cludes the more craft-like qualities of creative coding. All the interviewed teachers at Robotti identified the school in some way with the maker movement. Likewise, all the interviewed teachers, as well as those who answered the questionnaires, saw making by hand as an essential skill close to Kojonkoski-Rännäli's (1995)phenomenological view, which was considered to be an essential way of building a better understanding of the possibilities of digital technology. One teacher stated that building something from scratch integrates the child more into the world they are building (Interview 17.3.2017).

In the questionnaire, one of the teachers in Robotti wrote that the open-ended discovery and interest in taking things apart are aspects that he recognises in his teaching (Online Questionnaire answered 12.12.2014). Teachers also saw the using of tools and opening devices as

giving children the courage to investigate the digital domain. One teacher stated that one child was astonished that she was allowed to open a device even though there was a “Warranty void if opened” sticker on the back of it (Interview 6.7.2017). Another teacher talked about “creative tool use,” by which he meant that during the school year children had become proficient enough with tools that they could implement standard pliers instead of side-cutting pliers or try a lead in a circuit without instruction or fear (Interview 17.3.2017).

4.4 Artistic Freedom

The third perspective looks at creative coding through art and art education. Based on the interviews, questionnaires, and notes from the teacher meetings, the teachers accentuated the adventurous and investigative role of experiential art interpretation (Parsons 1987; Räsänen 2000) and post-modern art education (Efland 1996; Ettinger 1988). For instance, one teacher described open-ended enquiry as a helpful attitude: “I think that the art educational perspective is accomplished best through attitude. It allows for experimentation and mistakes are permitted. I try to make failures into observations and into courage to try again. Art education allows for creating and making without being an expert in the field.” (Interview 7.3.2017). Furthermore, art education was seen as diminishing preconceptions towards technology and at the same time evoking more balanced and even critical thinking about technology (Berry 2014; Bogost 2007). For instance, one teacher said they had listened to electricity through the speaker, rather than measuring that same electricity with a multi-meter. The teacher saw this listening effort as empowering an abstract digital environment by bringing the digital to sensory experience (Interview 17.3. 2017). Another teacher mentioned the importance of beautiful code: “Even if no one sees it, the way the code is written can be substantial and have an effect on the feeling of the work” (Interview 6.7.2017). Another teacher stressed the value of a piece of well-thought-out interactive artwork that can express the maker's thoughts, feelings, or opinions (Interview 21.6.2017). In sum, for the teachers at Robotti, creative coding appears to enable both teacher and student to leave both the preconceptions and misconceptions about digital technology behind and thereby approach digital technology from a much more personal perspective.

Students interactive art work. Photo by Roi Ruuskanen 2017.

4.5 The Challenges of Combining Art and Digital Technology

In general, both students and teachers appeared satisfied with the teaching at Robotti, although teachers did mention various difficulties. One of the most common problems among the teachers was the dichotomy between open-ended discovery and a strict top-down style of teaching.

For example, programming is a technology that requires that some rules be followed to produce an actual outcome. This following of instructions was difficult for some students and appeared tedious to some teachers. In the questionnaires, teachers wished for more guidance on where to draw the line between helpful, practical advice and creative discovery. Another common difficulty was finding ways to support the students so they would have the courage to explore and try independently.

The data collected from the students and their parents were erratic and too insufficient to draw broader conclusions, but an analysis of the questionnaires, the artwork and the field notes, appeared to be in line with the teachers' thinking. As an example, the children's more technologically oriented fantasy wishes at the beginning of the school year, such as creating a walking and talking destroyer robot, had morphed into more concrete thoughts about repairing a broken RC (radio controlled) car or creating an interactive art installation. A few students stated that they could now see programming everywhere and wondered how it had been built. Concerning the art, some students indicated that they now understood that art does not only have to be something made with pens and brushes, but it can, for instance, be a programmed effort.

Another set of common problems was preconceptions about digital technologies in general, generally seen as misguided by popular culture. For example, for some children, coding was a magical process that required supernatural skills, and/or hacking was something dangerous linked to terrorism or explosions. On the other hand, contemporary computer games and apps are now so sophisticated that the gap between them and the reality of what one can do alone becomes disappointing. In Robotti, one way to overcome these challenges was to create a shared goal for the semester in the form of an exhibition. The exhibition gave students enthusiasm to concentrate on their projects, even though the project would not have met their expectations at the beginning (Interview 21.6.2017). Another teacher added that the exhibition also alleviated parents' expectations and in that way students' expectations (Online Questionnaire answered 12.12.2014). Unfortunately, in an informal meeting, two teachers stated that some students do drop out because their expectations have not been met.

As the teachers at Robotti are a somewhat homogenous group, they share similar ideologies without necessarily much critical thought ever being expressed about these ideologies. To compensate for this bias, this research also interviewed two professors who were familiar with creative coding as well as giving a questionnaire directly to the participants on a creative coding course at the University of Turku. This group included both university students and arts and craft teachers already working in the field. The analysis of these materials coincided with the findings from Robotti and revealed new perspectives on creative coding.

The ubiquitous nature of digital technologies, as well as the need for education to discuss the nature of this ubiquity, was widely recognised. In general, creative coding was associated with the ability to generate critical thinking and an understanding of digital technologies. One teacher who took part in the creative coding course stated that learning programming in this way helped her to relate to digital technologies as well as see the importance of teaching programming in the basic curriculum (Finland recently started teaching programming as part of the basic curriculum) (Online Questionnaire answered 10.11.2016). Dr. Patton and Dr. Sweeney offered game studies as an alternative perspective on creative coding (Interviews 6.10.2017, 9.10.2016). For instance, Dr. Sweeney presented an example of how investing in designing one's own computer game can encourage a student to seek new ways to program that game to make it better.

One of the most common frustrations among all participants was the complexity and technicality of digital technologies. In particular, there was a fear of incompetence when surrounded by increasingly evolving digital technology and the uncertainty of not knowing where to start with the digital technologies. Dr. Sweeney indicated that critical thinking, as well as some technological knowledge, is needed among art educators to adjust their teaching accordingly. Indeed, the place and purpose for implementing digital technologies in art education should be most carefully considered (Interview 6.1.2016). Some of the questions raised by the interviewees as well as those who answered the questionnaire were: How much knowledge should one have of the technological foundations of digital technologies, or how much understanding should one have of the conventions and hierarchies of programming? Moreover, how much "artistic freedom" can one take with the boundaries of digital technology? In the example on "creative tool use", the teacher at Käsityökoulu Robotti remarked on a situation where the student independently tried to couple a LED light parallel to a direct current (DC) motor without a resistor:

This coupling produced the wanted effect (the LED light worked) but still was not correctly coupled (Interview 7.3.2017). Should the teacher then delve deeper into electricity and talk about current, voltage, and resistance, or should the teacher leave the project as it is because it now works?

Further still, if knowledge of electricity is required, then can one presume art educators will have this kind of knowledge? Dr. Sweeney and Dr. Patton pointed out similar problems when using digital software in general, i.e., making movies or animations, or editing using a photo editing application. All require some knowledge of their operations and even more to be able to understand their inner workings or advanced tools. How much technological guidance is needed in art education, and does that guidance and the choices of material hinder the reciprocity that is needed between experiential knowledge and abstract concepts? The answers to these questions will shed further useful light on the development of art education.

5. Conclusion and Future Research

This article examined creative coding as a method that combines the critical examination of our coded structures and its functions as an artistic tool to create art using digital technologies. Creative coding is widely understood as the creative use of programming where expression outweighs function. This article broadens that definition to include the critical inspection of digital technologies and the interplay between the individual experience and the abstract concepts that are so inherent in art education. The research here focused on the ways in which creative coding is implemented for successful teaching at the Käsityökoulu Robotti.

The primary outcome of this research is the beneficial use of creative coding to make digital technologies easier to understand. Creative coding was seen as giving space and freedom to students so that they can find their position regarding these digital technologies. Using creative coding was also seen as allowing the inspection of digital technologies from new, maybe less common, angles of analysis. As one teacher at Robotti said, it is great to be able to "collide students with themes and perspectives they would not otherwise ever explore" (interview 6.7.2017). The space for exploration was in the best cases also seen as giving students self-reliance and the courage to dig deeper. On the other hand, this perceived freedom was seen as challenging, as there are no clear guides as yet to follow, or even precise places to start.

As this research focused mostly on Käsityökoulu Robotti and the concept of creative coding is indeed a novel one, further research is still required. Methods for using the different aspects of creative coding can be developed further by providing art educators with easier access to creative coding. In sum, creative coding can prove to be a unique, valuable and exciting way to approach digital technologies. It offers multiple perspectives, such as the philosophical and societal aspect or the maker movement aspect. This focus can help each teacher when choosing an approach that is the most comfortable for them and their students.

References

Anderson, C. (2012), Makers: The New Industrial Revolution, London: Random House

Berry, D. (2016), The Philosophy of Software, London: Springer. http://doi.org/10.1057/9780230306479

Berry, D. and Dieter, M. (eds) (2015), Postdigital Aesthetics, London: Springer. http://doi.org/10.1057/9781137437204

Berry, D. M. (2014), Critical Theory and the Digital,London: A&C Black.

Bishop, C. (2012), 'Digital divide', Artform International, September

Blikstein, P. and Krannich, D. (2013), 'The makers' movement and FabLabs in education: experiences, technologies, and research' In Proceedings of the 12th International Conference on Interaction Design and Children (IDC '13), New York: ACM, pp. 613–16. http://doi.org/10.1145/2485760.2485884

Bogost, I. (2007), Persuasive Games: The Expressive Power of Videogames, Cambridge, MA: MIT Press.

Buechley, L. and Perner-Wilson, H. (2012), 'Crafting technology: Reimagining the processes, materials, and cultures of electronics', ACM Transactions on Computer-Human Interaction (TOCHI), 19:3, p. 21. http://doi.org/10.1145/2362364.2362369

Ceruzzi, P. E. (2012), Computing, Cambridge, MA: MIT Press.

Cox, G. (2013), Speaking Code, Cambridge, MA: MIT Press.

Cox, G., McLean, A. and Ward, A. (2004), 'Coding praxis: Reconsidering the aesthetics of code', In O. Goriunova and A. Shulgin (eds), Read_me Software Art and Cultures, Århus, Denmark : Digital Aesthetics Research Centre, University of Aarhus, pp. 161-74.

Dissanayake, E. (1992), 'The core of art', in Homo Aestheticus, Where Art Comes From and Why, New York: The Free Press, pp. 1–26.
Dougherty, D. (2012), 'The maker movement', Innovations: Technology, Governance, Globalization, 7:3, pp.11–14. http://doi.org/10.1162/inov_a_00135
Dufva, T., & Dufva, M. (2016). Metaphors of code—Structuring and broadening the discussion on teaching children to code. Thinking Skills and Creativity, 22, 97–110. http://doi.org/10.1016/j.tsc.2016.09.004
Dufva, T. (2017). Maker Movement: Creating knowledge through basic intention. Techne Series – Research in Sloyd Education and Craft Science, 24 (2), 129-141..
Efland, A., Freedman, K. and Stuhr, P. L. (1996), Postmodern Art Education, Reston, Virginia: National Art Education Association.
Erickson, M. and Räsänen, M. (1999), 'Building bridges, Experiential art understanding: A work of art as a means of understanding and constructing self', Studies in Art Education, 40:4, p. 381. http://doi.org/10.2307/1320557
Ettinger, L. F. (1988), 'Art education and computing: Building a perspective', Studies in Art Education, 30:1, p. 53. http://doi.org/10.2307/1320652
Fuller, M., Goffey, A., Robinson, D., Pold, S., Kittler, F., Mackenzie, A., et al. (2008), Software Studies, (M. Fuller, ed.), Cambridge, MA: MIT Press.
Freire, P., Freire, A. M. A. and de Oliveira, W. (2016), Pedagogy of Solidarity, London: Routledge. http://doi.org/10.4324/9781315422817
Giroux, H. A. (2011), On Critical Pedagogy, Bloomsbury Publishing USA.
Greenberg, I. (2007), Processing, Berkeley, CA: Apress. http://doi.org/10.1007/978-1-4302-0310-0
Halverson, E. R. and Sheridan, K. (2014), 'The maker movement in education', Harvard Educational Review, 84:4, pp. 492–94. http://doi.org/10.17763/haer.84.4.b1p1352374577600
Hatch, M. (2013), The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers, New York: McGraw Hill Professional.
Hayles, N. K. (2010), My Mother Was a Computer, Chicago: University of Chicago Press.
Heidegger, M. (2009), Vortrage und Aufsätze (Pfullingen), 11th ed., Stuttgart: Klett-Cotta. [Original work published 1952].
Knochel, A. D. and Patton, R. M. (2015), 'If art education then critical digital making: Computational thinking and creative code', Studies in Art Education, 57:1, pp. 21-38
_____ (2014), 'As we may publish: Digital scholarship and the future(s) of art education', International Journal of Education Through Art, 10:3, pp. 269–85: http://doi.org/10.1386/eta.10.3.269_1
Kojonkoski-Rännäli, S. (1995), Ajatus käsissämme. Käsityön käsitteen merkityssisällön analyysi. Turun yliopisto, Rauman opettajankoulutuslaitos. Nide 109 / Turun Yliopiston julkaisuja. Sarja C.
Kolb, D. A. (1984), Experiential Learning: Experience as the Source of Learning and Development, Englewood Cliffs, NJ: Prentice Hall.
Käsityökoulu Robotti (2017), 'Art & Craft School Robotti', https://www.kasityokoulurobotti.fi/swe-eng/. Accessed 16 January 2018
Lang, D. (2013), Zero to Maker, Sebastopol: Maker Media.
LeCompte, M. (1987), 'Bias in the biography: Bias and subjectivity in ethnographic research', Anthropology & Education Quarterly, 18:1, pp. 43-52. Retrieved from http://www.jstor.org/stable/3216340
Lessig, L. (2010), Code 2.0, New York: Basic Books.
Lieberman, Z. (2018), Weird Type, iOS program available at: https://itunes.apple.com/us/app/weird-type/id1352785248?mt=8
Martinez, S. L. and Stager, G. (2013), Invent to Learn; Making, Tinkering and Engineering in the Classroom (C. Sinclair, ed.),Torrance: Constructing Modern Knowledge Press.
McReynolds, E., Hubbard, S., Lau, T., Saraf, A., Cakmak, M. and Roesner, F. (2017), 'Toys that listen' in Proceedings of the 2017 CHI Conference, New York: ACM Press, pp. 5197–5207. http://doi.org/10.1145/3025453.3025735
Marner, A. and Örtegren, H. (2014), 'Education through digital art about art', International Journal of Education Through Art, 10:1, pp. 41-54.
McCarthy, L. (2016), 'Follower', Lauren McCarthy, http://lauren-mccarthy.com/Follower Accessed 13 February 2017.
_____(2011), 'Conversacube', Lauren McCarthy, http://lauren-mccarthy.com/Conversacube. Accessed 12 February 2018.
Morozov, E. (2014), To Save Everything, Click Here, New York: Public Affairs.
Noë, A. (2015), Strange Tools, Art and Human Nature, New York: Hill Wang.
Parsons, M. J. (1987), How We Understand Art: A Cognitive Developmental Account of Aesthetic Experience. Cambridge: Cambridge University Press.
PBS, (2013), The Art of Creative Coding. http://www.pbs.org/video/-book-art-creative-coding/. Accessed 12 March 2015.
Rushkoff, D. (2016), Throwing Rocks at the Google Business, London: Penguin UK.
_____ (2013), Present Shock, New York: Penguin.
_____(2012), 'Code literacy: A 21st-century requirement', Edutopia, http://www.edutopia.org/blog/code-literacy-21st-century-requirement-douglas-rushkoff. Accessed 12 March 2015

_____ (2010), Program or Be Programmed, New York: OR Books.
Räsänen, M. (2000), Sillanrakentajat [Bridgebuilders], Helsinki: Publications of the University of Art and Design, A 28.
Saariketo, M. (2015), 'Reflections on the question of technology in media literacy education', in S. Kotilainen and R. Kupiainen (eds), Reflections on Media Education Futures: Contributions to the Conference Media Education Futures in Tampere, Finland 2014, International Clearinghouse on Children, Youth and Media. Yearbook, vol. 2015, Göteborg: The International Clearinghouse on Children, Youth and Media, University of Gothenburg, Nordicom, pp. 51-61.
Shanken, E. A. (2001), 'Art in the information age: Technology and conceptual art', Leonardo, 35:4, pp. 433-38.
Shaw, D. and Wagelie, J. (2016), 'Studying artworks and their digital copies: Valuing the artist's aura', International Journal of Education Through Art, 12:1, pp. 57-69.
Stallman, R. M., Gay, J. and Lessig, L. (2009), Free Software, Free Society, Boston: Free Software Foundation.
Taylor, G. D. (2014), When the Machine Made Art, New York: Bloomsbury Publishing USA. http://doi.org/10.5040/9781628929980
The Finnish Association of Art Schools for Children and Young People (2013), Basic Education in the Arts in Finland, http://whm13.louhi.net/~youngart/wp-content/uploads/ 2013/09/Basic-Education-in-the-Arts.pdf
Turkle, S. (2011), Alone Together: Why we Expect More from Technology and Less from Each Other. New York: Basic Books.
Vaden, T. (2005), 'Digital nominalism. Notes on the ethics of information society in view of the ontology of the digital', Ethics and Information Technology, 6:4, pp. 223–31. http://doi.org/10.1007/s10676-005-0350-7
Wang, T. W. (2016), 'The landscape of websites for art education and a portrait of their designers', International Journal of Education Through Art, 12:2, pp. 195-210.

Digitalisation is augmenting and altering our culture as well as society in general. The term post-digital delineates a world where the digital is complexly intertwined with the physical world. Post-digital presents multiple challenges in regards to everyday life, as well as to culture and society, which requires comprehension of these technologies and their underlying code. Without an understanding of how these digital systems work, we are unable to participate in the construction of contemporary life fully. This dissertation examines the questions and problematics of code and digitality brought forward by the post-digital era. In particular, it focuses on the role and the means art education has in awakening a critical understanding of the digital constructs within our society.

Aalto-DD 72/2018

ISBN 978-952-60-7947-9 (printed)
ISBN 978-952-60-7948-6 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934 (printed)
ISSN 1799-4942 (pdf)

Aalto University
School of Arts, Design and Architecture
Department of Art
www.aalto.fi

BUSINESS + ECONOMY

ART + DESIGN + ARCHITECTURE

SCIENCE + TECHNOLOGY

CROSSOVER

DOCTORAL DISSERTATIONS