Computational empowerment in Ultra:bit

Bas van den Boogaard

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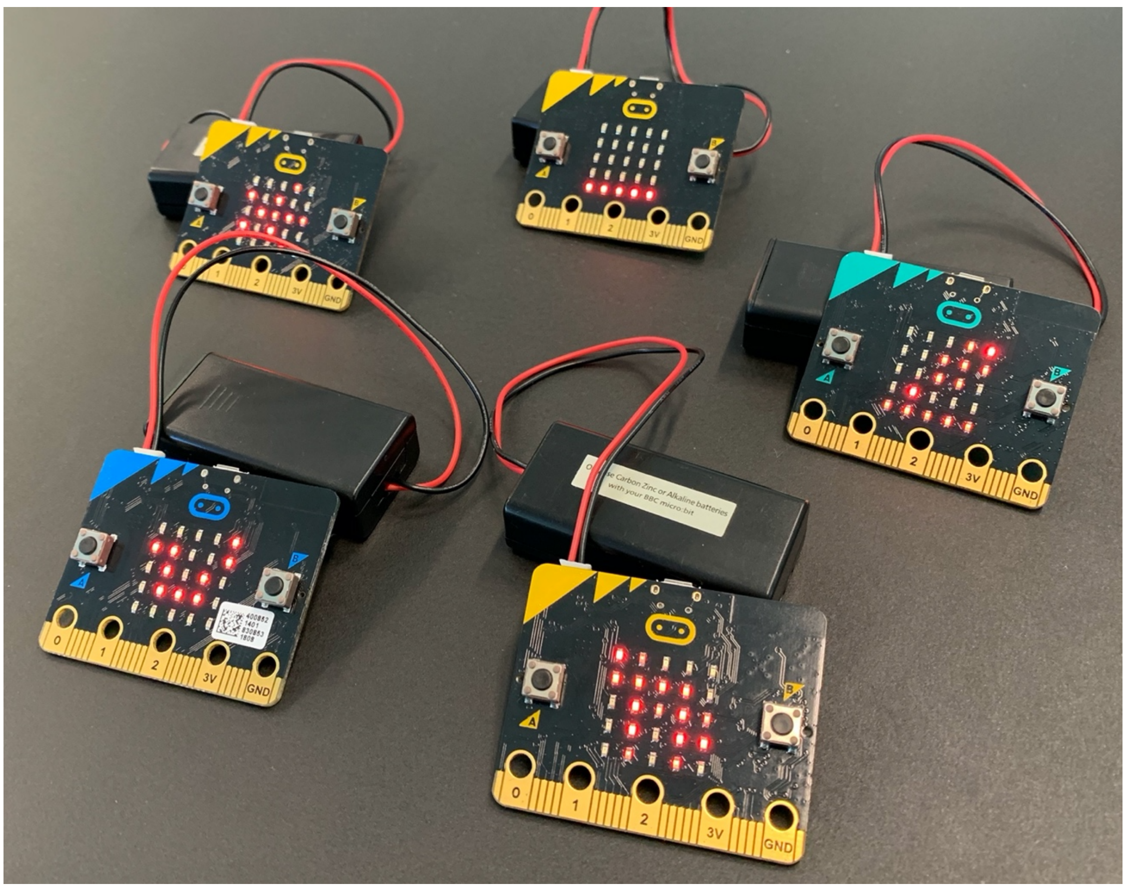

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Abstract

This thesis documents my investigation into the application of computational empowerment in upper primary and lower secondary education. In my research I use a codebook based on theory related to the educational concepts of computational empowerment, computational thinking, design thinking, and Bildung to analyze ethnographic data gathered at eight schools, as well as five interviews with teachers. While I was initially interested in how computational empowerment can be applied in its totality, I learned after the analysis that children need to pass three moments of foundational learning in order to be prepared. A first moment of foundational learning centers around teaching children a foundation in technology comprehension. In a second moment they can relate this foundation to the exercise of their independent thought and creativity in connection to technology. In the most advanced moment I have observed, the children learn to apply their technology comprehension, independent thought, and creativity in a design process that seeks to solve a real-world problem with a new technology or prototype.

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Introduction

Digitalization transforms society, the labor market, and individual lives, as it increasingly becomes embedded in all aspects of human activity (Iivari and Kinnula 2018; Dindler, Smith, and Iversen 2020). This demands education for new digital competencies. However, there is a significant difference in young people's chances to learn about and benefit from digitalization. Kinnula and Iivari (2019) speak of a digital divide between those that have the means to learn to use and create digital technology and those that do not.

In order to prepare children for the future labor market and give each child a fair chance at successful future, many countries are integrating computing and programming and increasing emphasis on STEM (Science, Technology, Engineering, and Mathematics) in national curricula (Carlborg et al. 2019; Ventä-Olkkonen et al. 2019). There are, however, still many challenges that need to be overcome in order for this integration to succeed, such as re-training teachers (Tyrén et al. 2018). And, as will be explored in the next chapter, there are many competing agendas for children's digital education that are researched and debated in the scientific community.

This thesis is primarily concerned with one such agenda, namely computational empowerment (for more on computational empowerment, see the next chapter). By investigating the practice of upper primary and lower secondary school teachers and pupils that participate in Ultra:bit, a technology education project that is strongly influenced by computational empowerment, I seek to contribute to developing a better understanding of how computational empowerment education can be facilitated for this age group.

This document is structured as follows. After this introduction follows a literature review of educational concepts that are influential in literature from the Fablearn, Interaction Design and Children, Participatory Design, and Child-Computer Interaction conferences and journals. Following this, I define the scope of my investigation and present my research question. Afterward, I will present Ultra:bit, the education project that I have selected as a case for my investigation, along with two previous investigations into Ultra:bit. This is followed by the method chapter. There, I will firstly present my overarching rationale for answering the research question, which ends with the formulation of sub-questions to my main research question. Then, I present the way I have gathered data and analyzed it. Finally, the method chapter contains the codebook that I have used for analysis as well as a section about research ethics. After the method chapter, I will present my findings. This is followed by a discussion chapter, in which I answer my research question, reflect on my methodology, and present the uncertainties and limits of my research. The very last chapter is the conclusion.

Review of educational concepts

In this section I explore various educational concepts that are prominent in literature from Fablearn, Interaction Design and Children, Participatory Design, and Child-Computer Interaction conferences and journals. These concepts are important for situating this thesis in a wider field of scientific study. Furthermore, the concepts of design thinking, computational thinking, Bildung, and computational empowerment form the theoretical foundations for the analysis of empirical material gathered for this work.

Making

Chu et al. (2015) trace the emergence of Making from the development of digital fabrication technology (like 3D printers and laser cutters), open-source electronics, and easy to use programming environments, to a wider participation in do-it-yourself activities, ultimately culminating in Making as a community, but also as an approach to teaching science, technology, engineering and math (STEM). Making, in the former sense, is characterized by a bottom-up approach to innovation, as well as community-operated workshops, called fablabs, where people can work on projects using computers, digital fabrication, and various other technologies and materials (Eriksson et al. 2018). The integration of Making in education stems from a growing interest in teaching children skills in relation to digital technology and teaching them that technology is something they can create themselves, rather than only use (Ventä-Olkkonen et al. 2019).

Concretely how Making should be integrated in education remains debated and under research (Ventä-Olkkonen et al. 2019). Technology Comprehension (in Danish: Teknologiforståelse), a Danish experiment to scale Making to a national discipline in lower secondary education, engages students in technology development, understanding technology's role in society, and critically reflecting on the role of technology in individuals' lives (Tuhkala et al. 2018, 73). Chu et al. (2015) propose STEM-related Making activities as a means to the end of developing a "Maker mindset", which is self-identification as a Maker, as well as the curiosity and self-confidence necessary to engage in Making activities. Christina Flores proposes teaching science using a Making approach, which she terms "problem-based science" (2018). Flores points out that this approach, based on learning through inventing and problem solving, fosters "Maker empowerment". This concept as defined by Clapp et al. (2016) entails “a sensitivity to the designed dimension of objects and systems, along with the inclination and capacity to shape one’s world through building, tinkering, re/designing, or hacking” (as cited in Flores 2018, 28).

The above examples are interesting, because they all aim to provide children with knowledge and skills that I think are important for children to have in the 21st century. However, the examples are also quite diverse when it comes to their aims. Another problem with Making in education is that it tends to focus on short-term interventions and that there is a very limited number of Making initiatives that aim for longer term integration in education (Ventä-Olkkonen et al. 2019). From my literature review it became clear that Making does not present a unified approach to education. It is used to describe diverse concerns, approaches and goals. Perhaps in the context of education Making can be said to be an umbrella term for approaches that seek to integrate technology and creation in education. In the following sections I will discuss education concepts that are in various ways related to Making. As I will show, design thinking stresses the importance of investigating problems, computational thinking is focused on structuring problems in such a way that computers can be used to (partly) solve them, and computational empowerment synthesizes influences from the other concepts to prepare children for their future in a thoroughly digitalized society.

Design thinking

Based on the work of Schön (1984), Löwgren and Stolterman (2004), and Randall, Harper and Rouncefield (2007) among others, Christensen et al. (2019) describe the designer’s characteristic way of working as follows. A designer works in a reflective conversation with a complex and messy world. This involves investigating the nature of problems and creating new understandings of them. Rather than assuming that problems are well-defined and solved in a relatively straightforward way, a designer has a sensitivity to the ill-structured or wicked nature of many real-world problems. According to Halverson and Sheridan (2014) ill-structured problems are complex, open-ended problems that are to a degree unspecified or under-documented and typically lack a single right solution (as cited in Pitkänen, Iwata, and Laru 2019). Similarly, wicked problems are defined by “societal challenges, dilemmas, ethical concerns, multiple stakeholders and unfamiliar domains” (Christensen et al. 2019, 637). In primary and secondary education children are insufficiently taught to navigate ill-structured and wicked problems, instead they are encouraged to see problems as clearly defined or tame, and to look for a single right answer to them (Christensen et al. 2019).

In concordance with Christensen et al.'s characterization of a designer's approach, Smith et al. define design thinking (DT) in an fablab-based educational context as "the ability to thoughtfully engage in design processes of digital fabrication, knowing how to act and reflect when confronted with ill-defined and complex societal problems" (Smith, Iversen, and Hjorth 2015, 21). Pitkänen and Andersen also regard DT primarily as a strategy for dealing with ill-structured and wicked problems (2018).

Various approaches to teaching DT became apparent from the literature review. Grammenos and Antona (2018) designed a five-hour crash course for children between the ages of 10 to 15. In the course children should learn basic DT, discover their own creative ability, and learn to collaborate on a design task. The course includes several design activities. In one of them children are challenged to design a spoon based on design requirements. In another they have to define a problem that they want to solve, devise a solution using a design approach, and collectively reflect and learn from the outcomes. DT is also taught in combination with digital fabrication in longer term education initiatives at schools (Smith, Iversen, and Hjorth 2015; Christensen et al. 2019). In one of two education initiatives documented in Smith, Iversen, and Hjorth (2015) for example, children from lower secondary education participated in a Fablab@school project, where during 45 hours of course activity they had to combine digital fabrication technologies like 3D printers, Arduino, and MakeyMakey with DT in order to tackle problems in contemporary society.

I agree with the authors cited in this section that children need to be taught to identify, investigate and transform wicked and ill-structured problems. Seen from the perspective of the Maker movement, if you want to teach children to design and build their own technology, then teaching them to identify, understand and tackle ill-structured and wicked problems will greatly improve their ability to cause meaningful change with their technical skills. In absence of the sensitivities of DT, you risk teaching children that programming and technology can only be used to solve tame problems. Or worse yet, use technology education to reinforce the impression that children already get from education, namely that problems are tame. Future technology-competent adults that have learned a great deal from Making in education, will still not be able to meaningfully impact technology related challenges, if they are not sensitive to their possibly wicked or ill-structured nature.

This is what a concern for DT in education should hopefully prevent. Herein lies its strength in comparison to other concepts included in this literature review. However, DT does not emphasize teaching children programming, electronics, digital fabrication, and computational thinking, which are increasingly seen as important for primary and lower secondary school curricula (Ventä-Olkkonen et al. 2019). This makes the concept flexible in relation to how it can be integrated in education but makes it insufficient to stand on its own as an agenda for 21st century education. In the next section I will explore computational thinking, which is focused on some of the areas that design thinking lacks.

Computational thinking

Computational thinking (CT) was conceived to make the ways of thinking employed by computer scientists appealing to other disciplines and the wider public (Wing 2006). Since then, various countries have begun integrating CT in curricula at all levels of schooling (Bocconi et al. 2016). CT involves important learning outcomes for modern education, such as critical thinking, problem-solving, programming and algorithmic thinking, which makes computational thinking critical for 21st century curricula (Troiano et al. 2019, 1).

Wing (2011, 1) defines computational thinking as: "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent." The Computer Science Teachers Association, which is based in the US but has internationally affiliated organizations, and the International Society for Technology in Education expand Wing's definition to include the following characteristics as well:

> "• Logically organizing and analyzing data
> • Representing data through abstractions such as models and simulations
> • Automating solutions through algorithmic thinking (a series of ordered steps)
> • Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
> • Generalizing and transferring this problem-solving process to a wide variety of problems" (CSTA and ISTE 2011, 1).

CT tends to be integrated in STEM education initiatives (Dindler, Smith, and Iversen 2020). My literature review contained many studies advocating various approaches, focusses and target audiences. Troiano et al. (2019) report that using game design in STEM, where early secondary school children can apply CT concepts creatively, leads to CT proficiency. Grizioti and Kynigos (2018) advance game modding, which is making alterations to existing games, as a promising approach for developing CT skills. Chalmers (2018) points to robotics as an effective way to instruct children in basic coding and CT, as it forces them to systematically give the robot sets of instructions to program it.

Apart from the strength of having many tried and tested approaches to teaching CT, computational thinking also has well-documented frameworks for assessing and evaluating children's development towards it. Some tools automatically analyze a student's work and assess their development towards CT based on that, Dr. Skratch being a prime example (Troiano et al. 2019). In contrast, Brennan and Resnick (2012) propose a multiple means of assessment approach. They distinguish three dimensions of CT that are important for assessment: concepts, practices and perspectives. CT concepts are common in many programming languages, which contain for example sequences (a set of steps) and conditionals, which define particular conditions for which a sequence or operation must be executed. Practices describe processes of construction and learning; how are children building their programs and how are they learning? Lastly, CT perspectives are a collection of all the different ways in which people that have developed the ability to think computationally look at themselves, their community and the wider world differently. Brennan and Resnick (2012, 11) give the example that children became aware of that Scratch, which is a programming platform developed by MIT, is a designed artifact that can be questioned and changed. Allsop (2019) builds further on Brennan and Resnick's framework and uses participant observation, interviews, children's journals, problem solving sheets, and completed games in a longitudinal study to assess primary school children's development in relation to computational concepts, learning behaviors and metacognitive processes characteristic of CT.

The weakness of computational thinking, as identified previously by Katterfeldt, Dittert, and Schelhowe (2015); and Iversen, Smith, and Dindler (2018) among others, is that CT lacks a concern for children's learning-to-be or Bildung.

Bildung

Bildung originates from Enlightenment educational philosophy by authors such as Wilhelm von Humboldt and Emmanuel Kant (Klafki 2012). The central question in the Bildung tradition is what constitutes an educated and cultivated human being (Biesta 2002, 345). Von Humboldt identified at the end of the 18th century that despite the great technological and practical scientific progress of the age, the development of inner human substance fell behind (von Humboldt 2012). Von Humboldt argued that scientific activity does not automatically lead to Bildung; by application of our faculties in scientific study we develop them, but in order for this to contribute to Bildung an individual needs to reflect the work back to their faculties and inner humanity, less they lose touch with themselves in pursuit of external successes in scattered knowledge and action (Lüth 2012, 67-69). It should be stressed that Bildung is not meant to be reserved for an academic elite but should be extended to every individual in society by means of public education, as was also von Humboldt's intention (Klafki 2012; Biesta 2002).

Klafki (2012) identifies four elements of Bildung. Firstly, self-determination, which entails the development of free and individual thought that emancipates one from determination by others. Secondly, Klafki argues that individuals need to be equipped to deal with the challenges they might meet in the future. Thirdly, while Bildung takes place on an individual basis, it is important that the individual is sensitive to society's problems and equipped to take part in addressing them. Lastly, Klafki (2012) distinguishes three dimensions of humanity that Bildung seeks to foster: a moral, a thinking and an aesthetic dimension. The moral dimension entails growing an individual's capacity for moral action. The thinking dimension is twofold. It applies to thinking that produces or applies knowledge, as well as the capacity to reflect on the moral and social implications of one's work. The aesthetic dimension allows one to experience meaning and freedom, which includes an individual's ability to feel in the face of human expression or natural phenomena, as well as the development of taste, imagination, creativity and sociability (Klafki 2012, 98).

Bildung is a timeless concept, which relevance extends beyond the time that it was conceived in. As established in the aforementioned, Bildung draws attention to the need for education to form the individual rather than solely focusing on the transmission of knowledge and the development of skill. It is up to the scholars and educators of the day to interpret what Bildung entails for the present and future.

As a case in point, Katterfeldt, Dittert, and Schelhowe (2015) propose three core ideas for implementing digital fabrication education that facilitates Bildung. The first is “be-greifbarkeit”, which describes making connections between the physical world and the virtual, as well as connections between abstract concepts and concrete projects.

> ”Programmable construction kits incorporate be-greifbarkeit very well: constructing and programming an artefact using a construction kit requires to align a mental concept with a tangible shape. Due to the nature of programming and circuiting, iterative cycles of redesigning and debugging are needed. The tangible object that is created serves to verify the mental concept and triggers reflection.” (Katterfeldt, Dittert, and Schelhowe 2015, 8)

Katterfeldt, Dittert, and Schelhowe stress that it is important that children are given enough time to create durable projects that can be tried out in action, in order to build the connections between mind, body and abstract concepts that are important for be-greifbarkeit. The second core idea is Imagineering, which is the process of creating personally meaningful projects from idea to physical implementation. In order to support Imagineering, the authors propose that digital fabrication initiatives not only link to problems form the real world, but also from personal imagination (Katterfeldt, Dittert, and Schelhowe 2015, 8). Lastly, the authors emphasize the importance of self-efficacy. Self-efficacy, which entails the ability to act autonomously in a digital world and the confidence to produce technology rather than only consume it, results from be-greifbarkeit and Imagineering (Katterfeldt, Dittert, and Schelhowe 2015).

However, Katterfeldt, Dittert, and Scholhowe are not the only ones that apply Bildung to 21st century education. The next concept in this literature review, eomputational empowerment, is in important ways, also linked to Bildung.

Computational empowerment

Like other concepts included in this literature review, computational empowerment (CE) is an educational response to the transformations of society and the labor market under influence of digital technology. Iversen, Smith, and Dindler (2018) frame CE as an expansion of computational thinking, adding a critical and reflexive stance to the challenges posed by digital technology and its effect on society, as well as including an aspect of empowering children to take part in technology development and to make informed choices about the role that technology plays in their lives.

> "Where CT is primarily occupied with understanding the concept of computing, CE seeks to engage children in broader questions such as the following: How does digital technology challenge our democratic rights and civic engagement? How are digital technologies altering our personal relations and our practices? How do we interpret intentions embedded in everyday technology and how can every child partake in society by remixing, redesigning or creating digital technology that is more attuned to visions for a better future?" (Iversen, Smith, and Dindler 2018, 1)

Dindler, Smith, and Iversen (2020, 2) define CE as follows.

> "We define computational empowerment as the process in which children and youth, as individuals and groups, develop the skills, insights and reflexivity needed to understand digital technology and its effect on their lives and society at large, and their capacity to engage critically and curiously with the construction and deconstruction of technology."

The combination of constructing and deconstructing technology is central to CE's model for how students should engage with technology (Dindler, Smith, and Iversen 2020). When constructing technology for others, students need to learn to see technology as a creative medium. In this process computational thinking and programming skills are important, although not exclusively. One also needs to relate to potential users, which requires studying their everyday practices, experiences and needs. This involves doing design research, prototyping and testing (Dindler, Smith, and Iversen 2020). Conversely, deconstruction involves reflection and analysis of technology produced by others. This process seeks to answer the following questions. How is the technology designed? How is it used? How does it affect people? What values and interests are embedded in it? (Dindler, Smith, and Iversen 2020, 7)

CE synthesizes influences from various educational agendas. From the concepts included in this literature review computational thinking, design thinking and Bildung had a considerable influence on CE. As an extension to computational thinking, CE inherits a focus on how computers can be used to solve problems, and how problems need to be approached to do this. Sensitivity to the needs, experiences, and practices of prospective users, as well as employing design research methodology to gain a greater understanding of the problem, is shared between CE and design thinking. Lastly, CE is not only concerned with teaching thought processes and skills, it also aims to equip children for living a good life in a thoroughly digitized society. Children are taught to be digitally self-determinant, to produce technology rather than just consume it, to identify society's problems related to technology and address them, and to reflect on the impact of the technology they create to name just a few ways in which computational empowerment is influenced by Bildung. For an overview of how all concepts included in this review relate to each other, see figure 1.

To get an overview over the different aspects of CE, I propose that the concept can be broken down in four dimensions. Firstly, programming and computation, which covers skills and knowledge relating to programming and computational thinking. The second dimension is about creativity with technology and design. This includes design thinking, as well as the creative skills and attitude required to become a producer of technology. Thirdly, CE has a socio-technical perspective that examines technology's impact on society, its role in individual lives, and the values that are embedded in it. Lastly, perpendicular to the technical, creative, and social dimensions of CE runs Bildung, which builds on knowledge and skills from all three and extends their value from the plane of practicality into the realm of forming individuals, cultivating their humanity, and empowering them to live meaningful lives in a society permeated by digital technology.

How best to apply CE in practice, is not yet clear. The concept is relatively new and it has only been applied in a few education initiatives, such as Fablab@school Denmark (Iversen, Smith, and Dindler 2018), and others that are still ongoing, such as Teknologiforståelse (Dindler, Smith, and Iversen 2020) and Ultra:bit (Danmarks Radio 2018c). Furthermore, CE does not yet have the sophisticated frameworks for assessing children's development towards it, which for example computational thinking does have. I identify that there remains room for research into how CE should be employed in upper primary and lower secondary education. In the next section I will discuss in depth how I aim to contribute to the state of the art in the field of Child-Computer Interaction, Fablearn, and Interaction Design and Children.

Concept	**Focus**	**What the concept lacks**	**Relationships to other concepts**
Making	Making is typically identifiable as a combination of digital	Making lacks a coherent agenda for education. There are	Making initiatives can have goals similar to initiatives focused on

	fabrication, programming, electronics and building with analogue materials.	many education projects that fall under the Making umbrella, but they all have a different focus.	the other concepts, possibly with the exception of Bildung, which was rarer in the literature.
Design thinking	DT emphasizes becoming sensitive to the wicked or ill-structured nature of real-world problems and learning how to investigate and approach these problems in order to develop (partial) solutions.	DT cannot stand on its own as an educational response to the challenges posed by increasing digitization of society and the labor market, because it does not in itself emphasize teaching skills like programming and electronics.	DT can easily be combined with the other concepts. I would argue that it is important for Bildung and computational empowerment, in order for these concepts to live up to their respective goals.
Computational thinking	The common denominator of many definitions of CT is the structuring of problems so that they can be solved with computers.	While it is often taught by means of creative processes, CT lacks an inherent concern for developing creativity and design thinking. Furthermore, neither is CT concerned with children's Bildung.	CT can be developed through Making based activities. Design thinking and CT are compatible and complementary. Computational empowerment is an extension of CT.
Bildung	Bildung is concerned with the cultivation of the individual and the formation of humanity in them. Rather than the transmission of skills and knowledge for their own sake, Bildung seeks to equip people for a good life.	Within the conferences and journals used for this literature review, Bildung could use more attention. How can Bildung be integrated in other educational approaches included in this review?	Bildung has had considerable influence on computational empowerment.
Computational empowerment	CE extends computational thinking to include a socio-technical perspective, as well as aiming to provide people with the	The concept is relatively new in comparison to the other concepts included in the review. CE needs more studies that	CE incorporates aspects of the other concepts in various degrees, design thinking is not mentioned explicitly

means to participate in the development of technology and extending them the means to make qualified decisions about the role of technology in their lives.	attempt to apply it in education, as well as frameworks for assessing children's (or adults') development towards it.	by CE's authors, however.

Figure 1: An overview over the included educational concepts based on the literature review.

Scope and research question

The research presented in this thesis contributes to state-of-the-art research in the fields of Fablearn, Child Computer Interaction, Interaction Design and Children, and Participatory Design in several ways.

As identified in the previous section, there is only a limited amount of studies about how computational empowerment can be developed. Furthermore, this thesis can be said to respond to several calls from the research community. First of all, Kinnula and Iivari (2019) express the need for more studies about design, education and empowerment aspects in Making projects with children. Secondly, Ventä-Olkkonen et al. (2019) and Tuhkala et al. (2018) identify that there is a tendency in the CCI-community to study out of school Making initiatives or short-term Making activities in a school context. They call for studies that focus on longer term education projects that seek to integrate Making into the education of children. As will become clear in the next chapter, which is about the case I study, this thesis will focus on a longer-term education project. In addition, Ventä-Olkkonen et al. (2019) also call for studies of an ethnographic nature that document what goes on in Making practices at schools. Finally, Iivari and Kinnula (2018) state that there is a lack of research about the empowerment of children through Making activities and how they experience this.

To contribute to research about children's education in Making, design thinking, computational thinking, Bildung, and computational empowerment in the research communities of Fablearn, Child Computer Interaction, Interaction Design and Children, and Participatory Design, this thesis aims to answer the following research question:

How can computational empowerment in all its dimensions be applied in educational initiatives aimed at upper primary and lower secondary school education?

The case: Ultra:bit

Danmarks Radio's Ultra:bit is a technology education project aimed at children in classes 4 to 8 of the Danish school system, in which children are between 9 to 14 years old (Holst 2020). DR's purpose with the project is that children, in a world where technology is increasingly present in all aspects of life, become more than users of technology by learning to produce technology and discovering what is hidden behind technology's surface (Danmarks Radio 2018a). Children that participate in Ultra:bit should, among other things, learn programming and computational thinking, but also develop towards computational empowerment (Danmarks Radio 2018c).

Ultra:bit was inspired by a similar project that ran in the United Kingdom in 2016, and it uses the same microcontroller as UK's project, called the micro:bit (Danmarks Radio 2018b). For more on the micro:bit see the next section. At its start in 2018 Ultra:bit was focused on one year of fourth graders and the project was only supposed to last three years, but the project has since expanded to include children in classes 4 to 8 and the duration of the project has been extended to 2023 (Holst 2020). Since eight out of ten schools in Denmark are participating in Ultra:bit, the project has more than 100.000 participants at the time of writing (Holst 2020). Schools have received a micro:bit for each participating student. It is mainly through programming and creating technological artefacts with the micro:bit that children are supposed to achieve the goals that DR has set for Ultra:bit (van den Boogaard 2019).

Apart from organizing the project, DR is also responsible for developing educational material that allows Ultra:bit to be integrated in already existing classes in Danish public education, creating television programs about Ultra:bit, as well as organizing Ultra:bit related educational events where classes from different schools can learn more (van den Boogaard 2019). See figure 2 for an overview over the main actors involved in Ultra:bit and their respective roles.

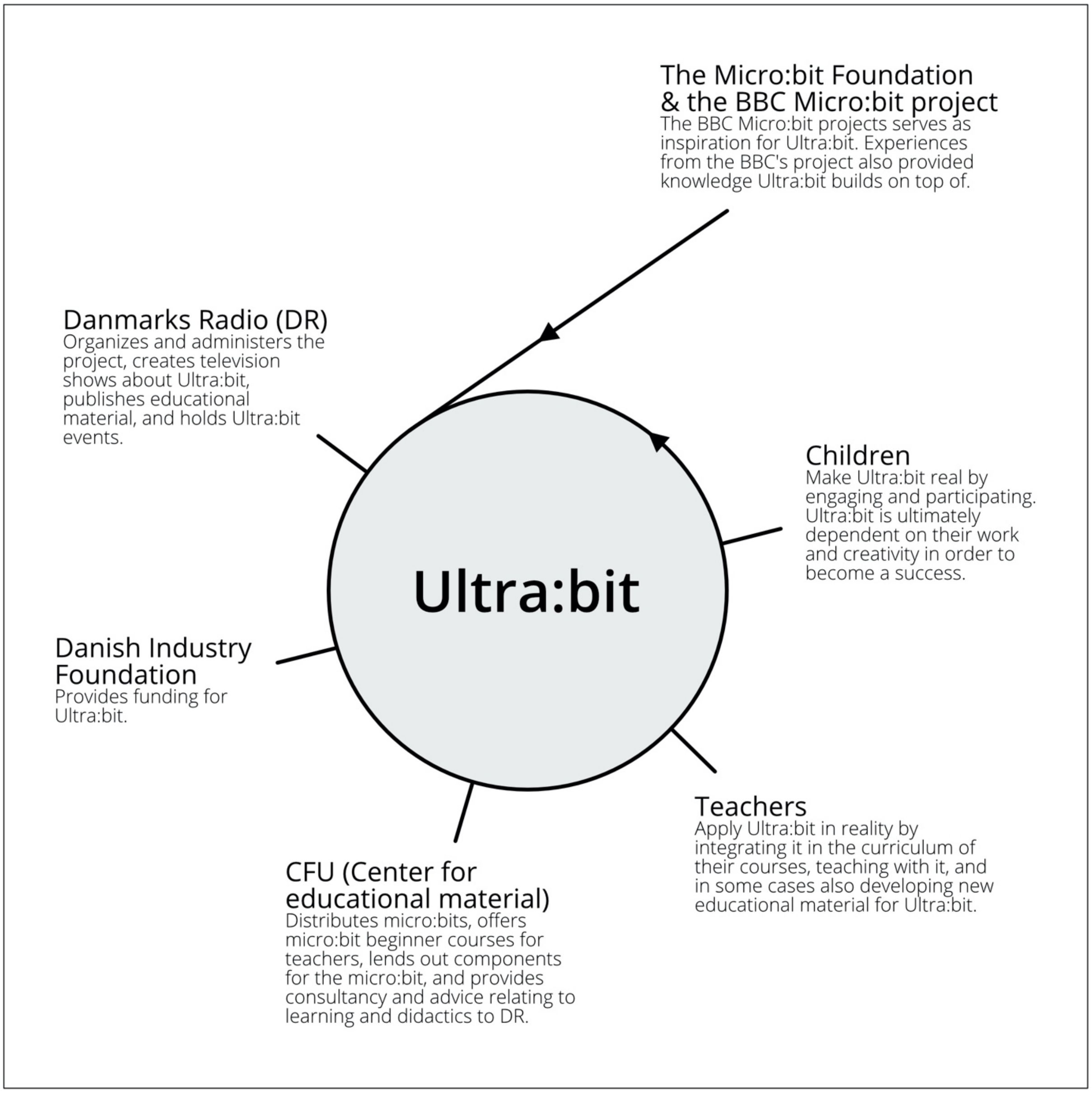

Figure 2: An overview over the main actors involved in Ultra:bit based on a section from last semester's report (van den Boogaard 2019).

It should be noted that there are other actors involved, such as libraries, governmental departments, and professional associations (Danmarks Radio 2018c). Furthermore, DR does not necessarily share my vision on who Ultra:bit's main actors are. In the next section, I will present the micro:bit, which is the microcontroller that plays a central role in Ultra:bit.

The micro:bit

The micro:bit (see figure 3) is designed to be easily programmable, while still allowing children to use it for many different purposes (Micro:bit educational foundation n.d.). It has several built-in sensors that allow it to measure light, temperature, acceleration and orientation. In addition, the micro:bit has connection pins that can be used to connect external components. Lastly, the micro:bit is equipped with several light emitting diodes (LEDs) that function as a rudimentary display.

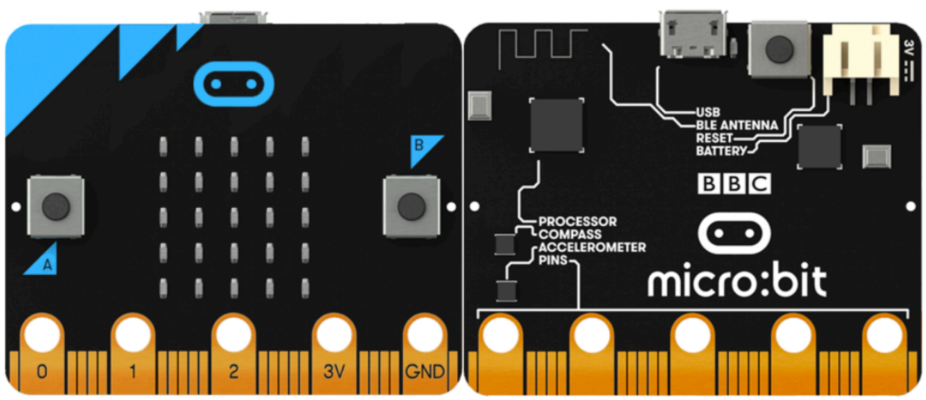

Figure 3: The micro:bit (Micro:bit educational foundation n.d.).

The micro:bit can be programmed online using Microsoft Makecode. Here, the user can dynamically switch between programming using block-coding (figure 4) and programming in Javascript (figure 5). “Block-coding involves coding through arranging and connecting visual elements. One builds a program by combining different kinds of visual elements, that each represent certain operations, functions or variables” (van den Boogaard 2019, 6). Coding in Javascript also uses operations, functions and variables, but is done by writing specific keywords and commands in text. The programs built on Makecode can easily be downloaded to the micro:bit with the help of a USB-cable.

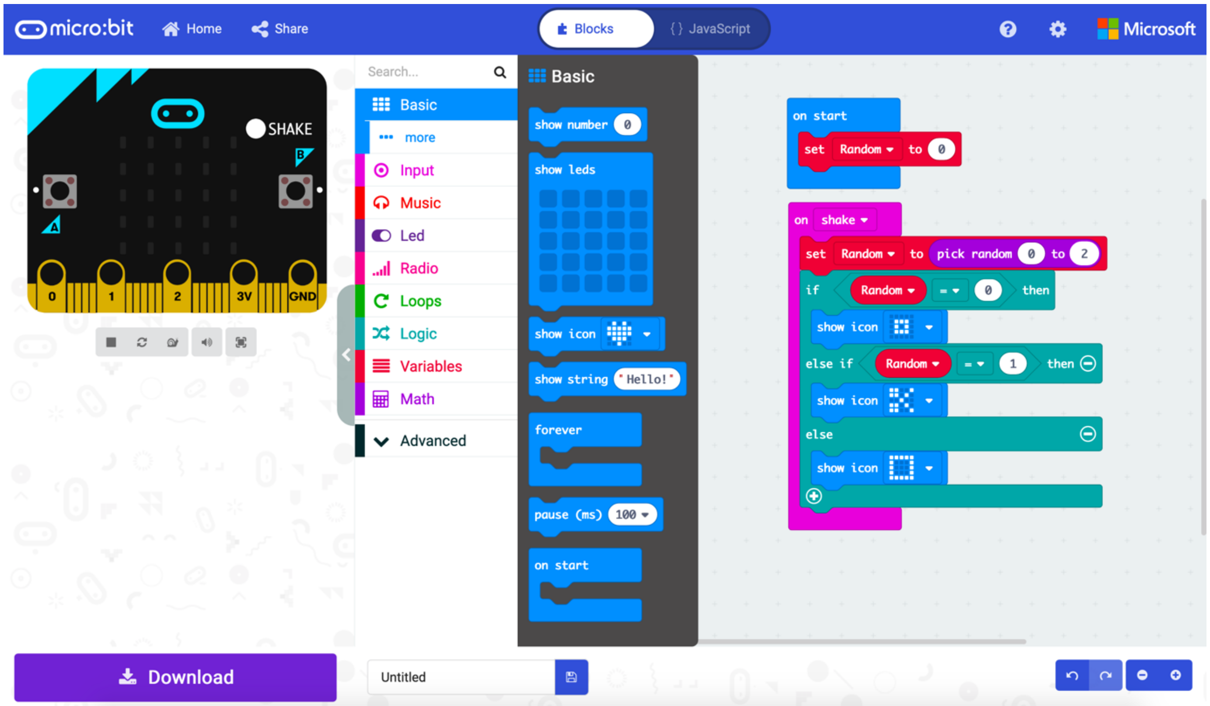

Figure 4: Block-coding on Microsoft Makecode.

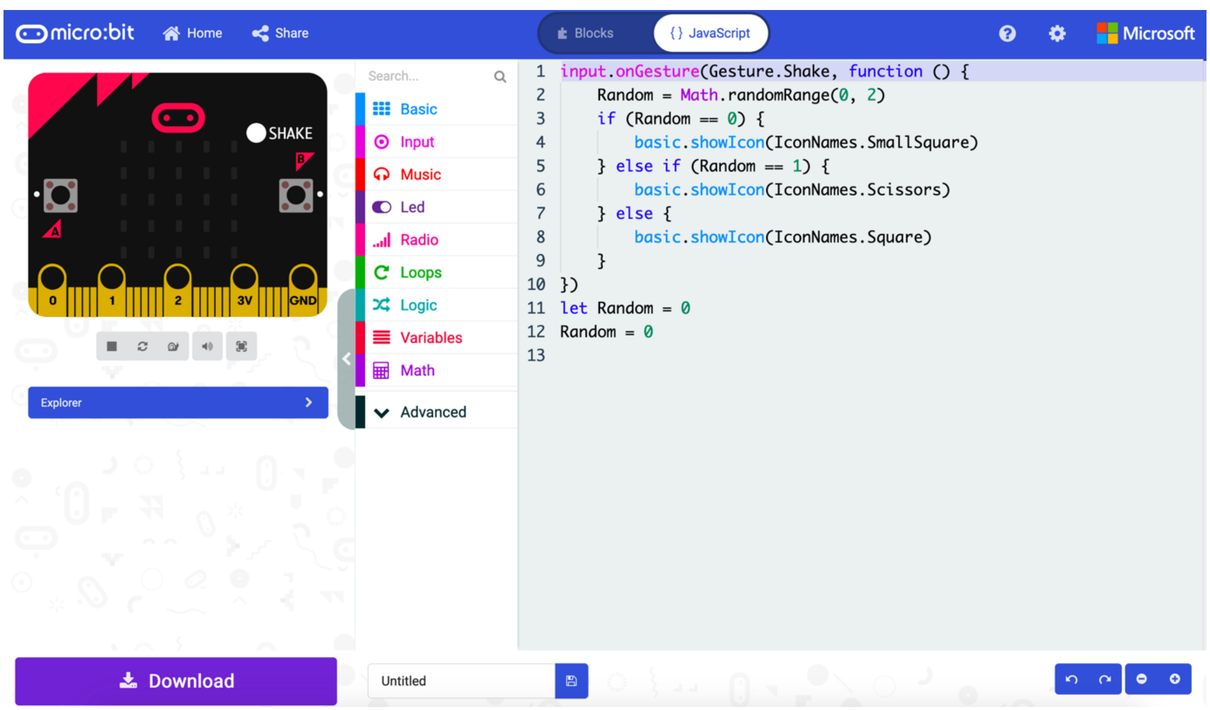

Figure 5: The same program as shown in figure 3, but now in Javascript.

As mentioned before, the micro:bit is perhaps the most important technology in Ultra:bit, as it is handed out to all participants and central to the marketing of the project. While participants are free to use whatever technology they want in Ultra:bit (Danmarks Radio 2018c), the education material on DR Skole almost exclusively uses the micro:bit and components that can be connected to it.

Ultra:bit's goals and ambitions

In this section a selection of relevant goals and ambitions that DR has defined for Ultra:bit will be explored. In order to teach children to navigate in a world that is filled with digital technology, Ultra:bit emphasizes the need for children to learn to create technology and critically reflect on its use (Danmarks Radio 2018c). In relation to creating technology strengthening children's creativity in general is important, but also their ability to understand technology. The latter entails that children learn to solve problems, develop products, and innovate using technology. DR envisions that children learn to better understand technology by engaging with it creatively (Danmarks Radio 2018c). Critical reflection on technology, on the other hand, is concerned with questions like: What is the purpose of technology? What impact does it have on people? How can the design of technology control our lives? How is technology not objective and innocent? According to DR, you need a critical perspective to act on a problem and build a better world. (Danmarks Radio 2018c).

In addition to the aforementioned, DR makes a point of Ultra:bit strengthening children's ability to autonomously act in world that is increasingly digitized (Danmarks Radio 2018c). This sounds remarkably similar to Klafki (2012) first element of Bildung, self-determination. While DR does not explicitly mention Bildung as a goal for Ultra:bit, they do have education material that focusses on "digital dannelse" (digital Bildung). Similarly, while DR does not mention design thinking in connection to Ultra:bit, they do want children to learn to develop innovative solutions to complex and real-world problems (Danmarks Radio 2018c). However, in contrast to Bildung and design thinking, DR does explicitly state growth in computational thinking and computational empowerment as goals (Danmarks Radio 2018c).

Lastly, Danmarks Radio has a thoroughly articulated vision for making sure that girls are included and inspired to participate on equal footing with boys (Danmarks Radio 2018c)[1].

Previous investigations into Ultra:bit

NEUC[2]

Naturfagenes Evaluerings- og Udviklingscentrum (NEUC, the Danish Natural science Evaluation and Development Center) published an intermediary quantitative evaluation of Ultra:bit, which includes a baseline study amongst 8419 pupils prior to participation in Ultra:bit and an intermediary effect study that explores results reported by 330 teachers after 3 months of participation.

The baseline study reports that 73 percent of children either did not know if they could code or knew that they could not. Seventy-nine percent of children answered that they would like to learn to code, however. Of the children that already could code before Ultra:bit, 88 percent expressed and that they would like to learn more. Concerning how children perceive gender in relation to programming, girls responded more often than boys that programming and technology are for everyone, 89 percent compared to 69 percent (NEUC 2019).

The effect study reports the following. Ninety percent of teachers reported that coding is easier than they thought it would be prior to participating in Ultra:bit. In addition, 85 percent of teachers answered that they believe to have been prepared to some extent to teach coding for creative solutions. In contrast, only 59 percent of teachers said the same about teaching their pupils to critically reflect on the use

[1] While gender does not play an important role in this thesis, I have investigated the role of gender in Ultra:bit in seventh semester and during my internship in 9th semester. I am not blind to the importance of a gender dimension to a technology and STEM education project like Ultra:bit. I think it is vitally important that education projects like these inspire and encourage girls to seek out professions in STEM fields. The reason that I have not focused on the gender dimension of Ultra:bit, is that my investigation in 9th semester, as well as investigations by NEUC have shown that Ultra:bit is largely living up to its goals in relation to encouraging and engaging girls (NEUC 2019; van den Boogaard 2019). Of course, it is possible to learn more about the role that gender plays in Ultra:bit, but for my thesis I was more interested in computational empowerment.

[2] This section is based on a section from my 9th semester report that presents the results of the same investigation (van den Boogaard 2019).

and effects of technology (NEUC 2019). In relation to their pupils' experience and development the teachers responded as follows. Ninety-five percent of teachers replied that their students think that it is easier to code than they thought before Ultra:bit. In addition, 90 percent of teachers reported that their students have said that technology is for them. However, only 50 percent of teachers reported any signs of their students being able to critically reflect on technology.

According to NEUC's conclusion (2019), the biggest problem that they have identified is that teachers are insufficiently equipped and supported to teach their pupils about the critical reflexive side of Ultra:bit.

Seventh semester report

As part of our seventh semester project (in 2018) four teammates and myself investigated how Ultra:bit was put in practice in different schools and how this compares to Ultra:bit's conceptualization by DR and other important institutional actors behind the project.

We conducted ethnographic fieldwork at two schools in combination with semi-structured interviews with the teachers involved in Ultra:bit. We analyzed this data using Actor-Network Theory. In the report we argue for the following. There is not one project Ultra:bit. Every teacher performs their own local version of Ultra:bit. The multiplicity of Ultra:bit means that it is possible for discrepancies to exist between how DR and other influential institutional actors have conceived the project and what the project is in practice at different schools. This in turn entails that the project can have different outcomes in each school (van den Boogaard et al. 2018). At the two cases in our study there was a big difference for example between what role children were playing in the classes. In one school, 6th graders taught 4th graders, while teachers focused on keeping order. In the other school a pedagogue took a leading role, but allowed his students to select one of several projects after their liking (van den Boogaard et al. 2018).

A plurality of approaches does not necessarily spell out trouble. However, when there are discrepancies between how DR imagines teachers should put the project into practice and how the teachers actually do it, this can result extra work for the teachers. We noticed a concrete mismatch between DR's idea of how much time teachers will need to prepare a class with Ultra:bit and how much time the teachers that participated in our study reportedly used (van den Boogaard et al. 2018). DR means for the education material to be plug-and-play, while the teachers in our study critically considered how Ultra:bit best should be integrated in the curriculum of their courses. Furthermore, the teachers also felt that they had to get familiar with the material in order to flexibly respond to problems that their pupils might encounter. If they are not familiar with the material and just follow the steps in DR's educational material, they would not be able to do that (van den Boogaard et al. 2018).

The investigation from 7^{th} semester has shown the need for studying the concrete practices at schools participating in Ultra:bit, as well as the experiences and challenges of teachers and pupils. Each school is its own case with important nuances to impart on Ultra:bit as a whole. An ethnographic and qualitative study therefore makes sense in order to shed light on local practice and learning outcomes. In this way the investigation from 7^{th} semester serves both as a foundation and a justification for the research presented in this thesis.

Methods

This chapter presents the methods I have used for gathering data and for analysis. However, firstly I will present the overarching rationale for answering the research question.

Overarching rationale

In order to answer how computational empowerment in all its dimensions can be applied in educational initiatives, I will look at how DR's attempt to apply CE in Ultra:bit works in practice. Since Ultra:bit is a large-scale project that has different avenues for teaching children, such as television programs, learning events, and classroom education by regular teachers, it is impractical to analyze it in its entirety with the limited means at my disposal. I have chosen to focus my investigation on those parts of Ultra:bit that take place in classrooms, because this is where teachers put the project in practice and where the pupils primarily learn and create with Ultra:bit. With this focus, several sub-questions to the research question come into view.

Research question

How can computational empowerment in all its dimensions be applied in educational initiatives aimed at upper primary and lower secondary school education?

Sub-questions

To what extent are all dimensions of computational empowerment put in practice by teachers that participate in Ultra:bit?

How do the pupils that participate in Ultra:bit education at school develop toward computational empowerment?

In order to answer the research question and sub-questions, I have firstly immersed myself in the Ultra:bit related practices of teachers and pupils in eight different schools using participant observation and informal interviews. Participant observation is particularly well suited for studying the different practices at schools, as well as getting both an insider and outsider perspective on what takes place there (Spradley 1980). Furthermore, observations, participation in lessons, and informal interviews with pupils during fieldwork have also provided me insight into how far children have come in their development toward CE.

To supplement the data gathered with participant observation and informal interviews, I have held four semi-structured interviews with teachers. In these interviews I was interested in their view on Ultra:bit's goals, DR's education material, and the development of their students, among other things. Involving teachers directly is especially important in order to answer how pupils develop toward computational empowerment under influence of Ultra:bit, as well as answering how DR's education material supports them in teaching. I have also collected Ultra:bit education material that is available online and analyzed it alongside the empirical material gathered with ethnography and the interviews. The education material that is available to teachers influences how the teachers put the project into practice, and thus indirectly the learning outcome towards CE. The analysis of the empirical material happened in several iterations of coding with a codebook that is primarily based on the theory presented in the review of educational concepts.

As a last addition to the overarching rationale for answering my research question, I will disclose the epistemological point of view underlying this thesis. As a researcher, I subscribe to Haraway's idea of situated knowledge (1988) and what Neyland terms reflexive ethnography (2008). As such, it is important to reflect on how my perspective is partial, particular, and influenced by my way of life, as well as how I influence the people and activities that I study and the outcome of this investigation.

Methods for gathering data

The majority of the data I used for this thesis I gathered during my internship at the Danish Broadcasting Corporation's school department (DR Skole), which lasted from the first of August till the 30th of November. This includes all the participant observation and informal interview data, as well as four out of five semi-structured interviews. As discussed in the previous chapter, this thesis builds further on the investigation that I conducted as part of my internship. The methods presented in this chapter are, therefore, not only the ones that I have used during data gathering this semester, but also the methods that I have used during my internship semester.

Participant observation

Together with informal interviews, participant observation was the main method used during fieldwork at schools. According to Spradley (1980), what is characteristic of all participant observation is that it studies a social situation, actors engaging in particular activities at a particular place. In the case of my research the places are classrooms, actors are teachers and pupils, and the activities are what takes place as part of education with Ultra:bit. Activities included for example the teachers introducing a task or problem, pupils coding or building, or pupils helping each other.

In order to gain access to classes for conducting participant observation, I wrote emails, in my capacity as an intern at DR Skole, to teachers that had registered for Ultra:bit. In the emails I offered my help with assisting their pupils with their assignments and answering their questions, in exchange for allowing me to conduct participant observation and informal interviews (see next section) in their classes. Teachers functioned as gatekeepers in my study, it was through the teachers that I gained access to the classes that were interesting for my investigation (Neyland 2008). Unfortunately, there were not a lot of teachers that were both interested in receiving me and worked on Ultra:bit during those months I was able to conduct participant observation. As a result of this, I have visited all classes and teachers that I could get access to. In contrast to what I had originally intended, namely to select schools based on the kind of neighborhood they were located in, so that my study would include children with different social classes and backgrounds. In the discussion chapter I reflect on how this impacts the validity and quality of my research.

A researcher doing participant observation dynamically switches between observing and participating in activities appropriate in the social situation (Spradley 1980). In my study, observation was useful for documenting how teachers approached their classes and how their pupils worked and behaved (van den Boogaard 2019). The way I could appropriately participate in the Ultra:bit classes, was by helping students with their work and answering their questions. I essentially played the role of a substitute or assisting teacher, since in most cases I was better at programming than the teachers, as I had experience programming micro:bit from my student job and internship at DR Skole. Teachers and students also treated me as a kind of teacher. Children would ask me if they were allowed to take a break or asked for my permission to move to a new assignment after having completed one. Teachers gave me free hands to assist pupils as I saw fit. In one school I even ended up in front of the class explaining a particular code on the board. My participation in the field gave me insight into the pupils' work, what they were able to do and understand, and what they experienced. Helping pupils was also important for building rapport, a form of trust. According to Spradley (1979), building rapport is important for fieldwork and interviews, because without it, informants do not feel comfortable to share their experiences or knowledge with you. Once I had worked with a group of pupils for a while, and they had gotten used to me, I would ask them questions for my investigation (van den Boogaard 2019).

As mentioned earlier in this chapter, participant observation involves developing both an insider and an outsider perspective on the social situation (Spradley 1980). The insider, or emic perspective, is that of the actors in the field under study, which is interesting in order to study how they talk about and understand their practice, as well as how different activities are meaningful for them (Neyland 2008). Conversely, the etic or outsider perspective allows the researcher to see the field from the perspective of the study's theoretical or methodological framework (Neyland 2008). The development of both emic and etic perspectives is an important reason for why I have chosen to use participant observation. The perspective of teachers and pupils, as well as a theoretical perspective on the practices relating to Ultra:bit is important for answering this study's research question. To foster an emic perspective developing close relations with the people in the field is important, and this takes time (Neyland 2008). I have spent a total of 37 hours at the different schools. At one school I have spent as much as nine hours, at another as little as one and a half hours. On average I have spent four and a half hours per school. I would have liked to spend more time at each school to gain a greater quality and quantity of data. Unfortunately, the schools that were willing to receive me had only scheduled limited hours for Ultra:bit education. In the discussion chapter I reflect on how this influences my thesis.

In order to generate empirical material from participant observation, a researcher writes fieldnotes. Since one cannot possibly write down everything that is said and done, a researchers' fieldnotes are a condensed account (Spradley 1980, 69). One tries to capture as many details as possible in rapid shorthand, which one translates into a coherent account after returning from fieldwork (Neyland 2008, 103). However, one's inability to capture everything that happens, also means that what a researcher chooses to observe and write down is influenced by their research question or agenda (Haraway 1988). In my case, as at the time of gathering data I was interested in children's development towards computational empowerment and their experiences participating in Ultra:bit education, these aspects are most pronounced in my fieldnotes. The edited and coherent versions of my fieldnotes, including the informal interviews discussed in the next section, can be found in appendix A.

Informal interviews

In parallel to participant observation I conducted informal interviews with teachers and pupils I had helped with their assignments and questions. According to Bernard (2006), informal interviews have no control or structure, and instead of recording the interviews, the researcher relies on taking notes and remembering the interviewee's responses. While I have relied on notes and memory in order to document responses, I do not agree that informal interviews have no control or structure at all. I agree with Brinkmann and Tanggaard (2015, 34) that no form of research interview is completely unstructured, since any such interview is still driven by a particular research agenda. This is illustrated by that I increasingly asked pupils a particular set of questions, save minor variations, the more time I spent in the field. In informal interviews with teachers we often talked about the program for the day, the teacher's goals for teaching with Ultra:bit, as well as how they experience teaching with Ultra:bit. With pupils the informal interviews tended to revolve around their projects, what they have learned, how they experience participating in Ultra:bit, as well as their interests and ideas for future projects. Informal interviews were an important addition to, if not an integral part of participant observation, as developing an emic perspective without asking the insiders directly, runs the risk of misrepresenting the actors in the social situation.

Semi-structured interviews

To supplement data gathered with participant observation and informal interviews, I have conducted 4 semi-structured interviews with teachers during my internship at DR's school department, and one semi-structured interview with a teacher over

Skype this semester. The four interviews from my internship used the same interview guide, which was focused on the goals the teachers wanted to achieve with their teaching using Ultra:bit, how they have approached their teaching, and how their pupils have developed under influence of this teaching. The interview held this semester had a different focus, namely the Bildung and socio-technical aspect of Ultra:bit and how the teacher has experienced teaching this to his pupils.

The following passage by Carl and Ravitch (2018, 875) describes my understanding of semi-structured interviews and this description generally fits with how I have applied this kind of interviews.

> "In semistructured interviewing, similar questions are asked across study participants, but all participants are not asked the exact same questions in the same order. Thus, in semistructured interviews, the interviewer tends to ask individualized, follow-up questions during the interview. Semistructured interviews tend to use a semistructured interview instrument/protocol in which questions are listed on an interview guide, but the questions are not always asked in the exact same order, and participants' responses are open-ended, meaning that there are no predetermined answers from which to select."

Brinkmann and Tanggaard (2015) differentiate two kinds of questions asked in semi-structured interviewing: introductory questions and follow-up questions. The introductory questions encourage the interviewee to start talking about a particular topic. The follow-up questions are meant to steer the conversation and achieve greater depth where this is relevant for the researcher (Brinkmann and Tanggaard 2015, 41). In the interview guides that I have used, I have prepared introductory questions and follow-up questions that can be used to ask for information that does not naturally come up.

The four interviews conducted during my internship took place after I had done participant observation at the classes of the teacher in question. So, at the time of interviewing I had already built rapport with them. I selected to interview the teachers that had come furthest in teaching pupils with Ultra:bit, as they would best be able to recount the development of their pupils. I interviewed these teachers at their school and recorded the interviews, in order to transcribe them afterward. The transcriptions of the interviews can be found in appendix B.

As mentioned earlier, the interview that was held this semester was conducted over Skype. Interviewing over skype has advantages and disadvantages. Neither participant nor researcher have to travel, and the participant is in their own environment, and therefore probably more relaxed (Sharp 2019). On the flipside, a bad connection can impact the quality of the recording, and body language is generally harder to see (Sharp 2019). While conducting the interview the audio quality was at times problematic, which required my interviewee to repeat themselves. Fortunately, I was able to transcribe the recording without problems.

Documents

The last sources of data for this investigation are education material that DR's school department publishes online as part of Ultra:bit and the webpages on which the material is presented and made available to teachers and pupils. I have treated these as documents. The reason that I classify the education material and the webpages as such, is because they fit Brinkmann and Tanggaard's (2015, 154) definition for what a document is, namely language that is fixed in text and time. One could argue that webpages are not fixed in time, but by downloading them as they were at a particular time (April 21, 2020) and storing them in a medium that will not be updated, I have made them so.

As the website of DR's school department is rich in both webpages and education material pertaining to Ultra:bit, my choice for which documents to include was a careful one. As suggested by Neyland (2008), I have based my selection on how the documents can be linked to my observation data. Therefore, I have selected education material that was used in the classes that I have observed. The webpages I have selected provide an overview over the different kinds of education material that are available and present different aspects of Ultra:bit to teachers, such as didactics, design processes, and reflection on technology. An overview over the education material provides context for the material that was used in the classes I observed. How Ultra:bit is presented to teachers allows for comparison between how the teachers put Ultra:bit in practice and how DR has envisioned this. Selected webpages of DR's school department's website can be found in appendix C. Selected education material can be found in appendix D.

Ethics

Since gathering my data involved contact with children, well considered research ethics are important. I had to navigate how I would obtain appropriate informed consent as well as children's assent, and how to protect the anonymity of pupils and teachers. Furthermore, I had to consider how I could gather data while being careful not to hamper children's learning or undermine the teacher's authority. Prior to gathering data, I have written ethical considerations, which helped me to navigate these aforementioned challenges and more. These considerations can be found in appendix E. This text did not only include considerations relating to contact with children, but also in relation to teachers, schools, and the institution that hosted my internship, Danmarks Radio. For the interview that I have conducted on the 16th of April 2020, I have applied the same ethical standards as for the interviews conducted during my internship.

Method of analysis

The data gathered with participant observation and interviews, as well as selected education material and webpages from DR's school department were analyzed together in the manner that is described in this section. The data was analyzed using two cycles of coding and analytical memo writing.

First cycle of coding

For the first cycle of coding I have used Elaborative coding. Elaborative coding is coding using a codebook based on theory from other studies, and can be used to strengthen, modify or disconfirm said theories (Saldaña 2013). This is appropriate, because I apply theory relating to computational empowerment to the empirical material I have gathered about Ultra:bit in order to contribute to the theory's further development. Furthermore, according to Saldaña (2013), elaborative coding can be used for the re-analysis of data from a previous study. This is significant, since I use data that was gathered during my internship. In the next subchapter I present the codebook that I have developed based on the theory that was presented in the literature review. This is the codebook that was used during the first cycle of coding.

In parallel to the coding of the first cycle, I have written analytical memos. I have written analytical memos on several topics suggested by Saldaña (2013). How can the different components of the study be connected? How are the emerging categories transferrable to other populations and theory? What can be researched in the future? I have also written more generally about how the analysis was shaping up and what kind of analytical patters where emerging.

Codebook

In order to compose a codebook, I have taken computational empowerment, computational thinking, design thinking, and Bildung and I have broken them up in their constitutive parts. The reason that I have not used Making is that this concept does not have a uniform approach to education, making it unclear how the concept should be coded. This resulted in the following list of initial codes:

Number	**Educational concept**	**Part**
1	CE	Programming and computation
2	CE	Creativity with technology and design
3	CE	Socio-technical perspective
4	CE	Bildung
5	Bildung	Self-determination
6	Bildung	Equipped for future challenges
7	Bildung	Sensitivity to society's problems
8	Bildung	Fostering Humanity – Moral
9	Bildung	Fostering Humanity – Thinking - application
10	Bildung	Fostering Humanity – Thinking - reflection
11	Bildung	Fostering Humanity – Aesthetic
12	DT	Sensitivity to ill-structured or wicked problems
13	DT	Investigating problems
14	DT / CE	Engaging in design processes
15	CT	Defining problems
16	CT	Organizing data
17	CT	Abstraction

18	CT	Algorithmic thinking
19	CT	Efficiency mindset
20	CT	Generalizing

Figure 6: A list of the initial codes.

Subsequently, in order to reduce overlap between constitutive parts of different concepts, I have broken up and merged several codes. “Creativity with technology and design” was reduced to “creativity with technology”, because the design aspect is already covered by the different parts of design thinking. I have broken up “programming and computation” up likewise. “Programming” was deleted, however, because it would be to general to be a practical code. I have also merged Klafki’s two aspects of “thinking” in “fostering humanity”, because just the application of knowledge is too broad to be a usable code on its own. Now that it is merged with reflection, they together describe the process of applying knowledge while maintaining a reflexive metacognition. I have merged “socio-technical perspective” and “sensitivity to society’s problems”, because within the context of a technology education project, both codes describe social and societal challenges and opportunities relating to the introduction of technology. Lastly, I have added codes for the concepts of computational empowerment, computational thinking, design thinking, and Bildung in general.

In order to test the codebook and its inclusion criteria, I applied it to one day’s participant observation and informal interview data, along with one teacher interview. Based on this initial test, I have expanded the inclusion criteria for certain codes. These expanded inclusion criteria can be found in the last column of the codebook. Finally, this resulted in the codebook that was used for the first round of coding (see appendix F). See the figure below (figure 7) for the codes and their connection to theory. For an example of inclusion criteria see figure 8.

Code	**Connection to theory**
Creativity with technology	For computational empowerment it is important that children become more than passive consumers of technology, they need to become active producers of it. Children need to learn to see technology as a creative medium. They must learn to create with it (Dindler, Smith, and Iversen 2020).

Socio-technical perspective	Computational empowerment is concerned with questions relating to technology's impact on society and individual lives (Iversen, Smith, and Dindler 2018). Sensitivity to society's problems in relation to technology is also important from a Bildung perspective. According to Klafki (2012), a Gebildet individual is sensitive to the problems of society and future generations.
Self-determination	The first of Klafki's (2012) four aspects of Bildung. Self-determination comes from the development of free and individual thought. This concern within the Bildung tradition aims to equip individuals with whatever is necessary to prevent determination by others. Within the context of Ultra:bit, developing children's self-determination may take the form of teaching them to identify how technology is used as an instrument of power and how it can influence people, as well as teaching them how to counteract, subvert, or eliminate these influences.
Equipped for future challenges	Klafki's (2012) second aspect of Bildung emphasizes that children should not be educated for the world as it is now, but they need to be equipped to meet challenges and act on opportunities they will meet in the future. Ultra:bit can be seen as part of an effort to prepare children to navigate an increasingly digitalized society.
Fostering Humanity – Moral	Within the Bildung tradition there is attention for developing an individual's capacity for moral action (Klafki 2012). Within the context of Ultra:bit, teaching children to reflect on how a technology they design could impact others or teaching them about the moral implications of (ab)using a technology, might be a way of accomplishing that.
Fostering Humanity – Thinking	Thinking, within the context of fostering humanity, is about applying knowledge to create or learn something new, whilst simultaneously maintaining a degree of reflexivity that is concerned with what is justifiable and humane (Klafki 2012).
Fostering Humanity – Aesthetic	This aspect of Bildung allows one to experience meaning and freedom. It furthermore enables individuals to feel in response to human creation and natural phenomena. Lastly, it is concerned with

	the cultivation of an individual's creativity and sociability (Klafki 2012).
Sensitivity to ill-structured or wicked problems	A core aspect of design thinking is the ability to identify and approach ill-structured and wicked problems (Christensen et al. 2019).
Investigating problems	Solving a problem requires a thorough and nuanced understanding of it. Learning to understand the perspectives of relevant stakeholders is a part of that. These processes are important for both design thinking and computational empowerment (Christensen et al. 2019; Dindler, Smith, and Iversen 2020).
Engaging in design processes	This essentially describes moving from a problem to a solution. It involves processes such as design research, brainstorming, prototyping, and testing (Dindler, Smith, and Iversen 2020).
Defining problems for computation	Wing (2011) defines computational thinking as defining problems and their solutions in such a way that a computer can be used to solve the problem.
Organizing data	According to CSTA and ISTE (2011) organizing and analyzing data logically is also an important aspect of computational thinking.
Abstraction	Abstraction in computational thinking is about hiding the right details to make a problem easier to solve without losing important information (Bocconi et al. 2016).
Algorithmic thinking	Algorithmic thinking is concerned with designing algorithms, which are sequences of steps that can automate a process (CSTA and ISTE 2011).
Efficiency mindset	I use this code to encapsulate the following. "Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources" (CSTA and ISTE 2011, 1).
Generalizing	A problem is examined in light of previously solved problems or a problem solving process is transferred to other problems (Bocconi et al. 2016; CSTA and ISTE 2011).
Computational Empowerment	This code is meant to encompass computational empowerment in its entirety, as discussed in the review of educational concepts.

Computational Thinking	This code is meant to encompass computational thinking in its entirety, as discussed in the review of educational concepts.
Bildung	This code is meant to encompass Bildung in its entirety, as discussed in the review of educational concepts.
Design Thinking	This code is meant to encompass design thinking in its entirety, as discussed in the review of educational concepts.

Figure 7: The codes used in the first round of coding and their connections to theory.

After the first round of coding, I read through all the notes I took along the way. In these notes I have recorded tensions between the empirical material and the theoretical framework, possible links between different codes, and ideas for inductive codes to supplement the codebook. Furthermore, I have explored the data that I have coded by reading it through and by experimenting with different ways of visualizing the results, such as matrices and charts. I have also paid attention to particular passages in the empirical material that were coded under many different codes. These nexus passages, as I call them, are interesting, because they show possible connections between different parts of this study's theoretical framework. In addition, I have written analytical memos and reflections on the outcome of all the aforementioned procedures, in order to further my understanding and sense of direction in the analysis. Lastly, since the codebook did not cover certain analytically interesting passages in the data, I decided to add two inductive codes to the codebook, as well as a new concept from the literature, because this concept adequately covers a gap in the codebook (See figure 8).

Code	**Description**	**Inclusion criteria**
Technology comprehension	Several teachers have pointed out that teaching their pupils to better understand technology is an important or even the main goal for their participation in Ultra:bit. This includes understanding	Passages where children learn or are taught to understand technology. Reflections, communication, behavior, or presentations relating to this. Children struggling to understand technology,

	programming, computation, sensors, actuators, and electronics. Children need to learn to recognize technology in their everyday lives and understand how these technologies work. This knowledge serves as a foundation that allows children to critically reflect on technology and to use it creatively.	programming, or electronics. Passages that illustrate that children understand technology and can recognize them in their everyday life. Instances where a foundational understanding of technology, which allows children to use technology creatively or reflect on technology, is apparent.
Engagement	From both participant observation data and teacher interviews it became clear that some students are more motivated and interested in Ultra:bit than others and that this has a significant impact on their learning and experience.	Data that describes or illustrates differences in engagement, motivation or interest, as well as the influence this has on pupils' learning or experience.
Be-greifbarkeit	Be-greifbarkeit describes making connections between the physical world and the virtual, as well as connections between abstract concepts and concrete projects. Through creating with technology, the abstract concepts and models relating to programming and electronics are applied. While playing	Instances where children are trying out, testing, or playing with their creations, as well as communication, reflection, presentations, and behavior related to this.

	with or testing the outcome, these abstract concepts and models become graspable. (Katterfeldt, Dittert, and Schelhowe 2015).	

Figure 8: The new codes that will be added to the codebook for the second round of coding.

Second round of coding

With these aforementioned additions the codebook was ready for the second round of coding. After the second round of coding, I employed the same techniques to make sense of the coded data. I read the notes I had written during the coding, explored matrices and charts, made a mind map, inspected nexus passages, and wrote new analytical notes. In the next chapter, I will present the results of the analysis.

Findings

In this chapter I will present the discoveries made in the analysis. The interactions between the theoretical framework, as translated into the codebook, and the empirical material is what led to this study's main findings. In what follows I will firstly provide an overview over the outcome of the analysis and introduce the main findings I have chosen to focus on. Subsequently, I will outline these findings while referring to relevant passages from the data. Along the way the research question and the sub-questions will be answered implicitly. In the discussion chapter I will formulate explicit answers to the research question and the sub-questions.

Overview

Appendix G contains a matrix that shows how many times each code was coded alongside any other code. In the matrix the yellow cells indicate how many times any code appeared in total. The green cells show two codes co-occurring 40 times or more. I chose forty as a bar for selecting the most central codes, as a lower value would include to many codes to be meaningful, and a higher would exclude to many, leaving not enough relationships to explore and build theory on. “Abstraction”, “algorithmic thinking”, “creativity with technology”, “defining problems for computation”, “engaging in design processes”, “self-determination”, “socio-technical perspective”, and “technology comprehension” co-occur 40 times or more with at least one of the other codes mentioned. Their relationships to each other play an important role in the main findings that I will present in the findings chapter.

Though the aforementioned codes and their relationships are the most pronounced in the data, they are by no means the only interesting relationships present. Other potentially interesting connections between codes that I have not chosen to focus on include the relationships between “engagement” and central codes like “technology comprehension” and “creativity with technology”. Investigating these relationships could perhaps lead to a theory about what role engagement, motivation, and interest play in how children develop in education for computational thinking or computational empowerment. Another example is the relationships “equipped for future challenges” has to the rest of the codes. As discussed in earlier chapters, preparing children for their future lives in a thoroughly digitalized society is an important aspect of computational empowerment and Bildung, and an important goal for Ultra:bit. However, what role does preparing children for future challenges play in practice in the teaching and learning taking place in the classes I have observed? Lastly, there is also data that was left uncoded, because of my focus on computational empowerment and children's development towards it. Had I instead chosen to focus on children's experience of participating in Ultra:bit for example, then the data would presumably have been coded differently.

In the next section I will begin presenting the main findings of the thesis. As will become clear, even though the teaching and learning that I have observed in practice does not live up to the theory, the learning taking place can help children achieve goals related to computational empowerment in later stages.

Rudimentary computational empowerment education

A first finding became apparent from the friction between the theoretical ideals for education presented in the academic literature (see the review of educational concepts) and the imperfect and at times rudimentary education in practice, as illustrated by the data. In what follows, I will firstly illustrate the tensions between the codebook and the empirical material by referring to excerpts from the data, codes, and analytical memos.

In the following passage from my fieldnotes a teacher is explaining an aspect of programming to his pupils.

> "He goes on to explain 'if this, then that' logic to the children. He gives examples of projects where they can use if-statements to do something if a particular condition is fulfilled. I think that this might be an interesting approach to teaching children basic computational thinking. One example he gives is a water pump and solar panels. If there is sunlight, then pump water to a high place." (Fieldnotes Lykkesten Skole, September 20th, 2019).

While analyzing this passage I wanted to code it under algorithmic thinking, amongst other codes. However, when comparing this excerpt to the inclusion criteria, it does not seem as if the criteria are met.

> "Pupils break larger processes up in smaller sequential steps, or are taught to do so, as well as communication and reflections relating to this." (Codebook: inclusion criteria for algorithmic thinking).

To resolve the tension between the data and the inclusion criteria, I decided the following.

> “I think that ‘if this, then that’ logic falls short of algorithmic thinking in its entirety. However, this kind of logic is an important aspect that children need to master in order to progress to algorithmic thinking in a fuller form. I have coded this under algorithmic thinking.” (Analytical memo written during analysis).

This example illustrates that while in essence the datum does not satisfy the inclusion criteria entirely, it does demonstrate algorithmic thinking in rudimentary form and illustrates that a foundation for a fuller form of it is being built. In the next example a teacher recounts an assignment where her pupils had to program a fortune telling machine.

> ”In the beginning we usually make a fortune teller. It shows how much percent chance there is for something particular to happen. And then my pupils have to make a random function themselves. And that leads to a good conversation about what is happening in the background when we ask the machine to make a prediction. It is running a code that has nothing to do with reality. It just shows a random number. In that way my students can critically reflect on [the technology and its use].” (Teacher interview, Dronning Margrete Skole, quote translated from Danish).

Since the teacher mentions that her pupils critically reflect on the technology and how it is used, I thought to code this under self-determination.

> “Instances of teachers or pupils communicating about children’s or people’s self-determination, as well as reflections on this topic. Assignments meant to teach children to be more self-determinate in relation to technology, as well as presentations, behavior, and responses to these will be coded under Self-determination.” (Codebook: inclusion criteria for self-determination).

I think that it would be hyperbolical to claim that this assignment strengthens the children’s self-determination to such a degree that they are able to resist technological determination by Silicon Valley technology giants and that children become able to critically reflect on the role that digital technology plays in their lives. However, the excerpt does show the following.

> "Children are taught not to take for granted what technology tells them. Instead they investigate why technology gives the output that it does. They can critically think about this. This teaches them to think for themselves in relation to technology, therefore I have coded it under Self-determination." (Analytical memo written during analysis).

In the last example I will give of friction between the codebook and the data, a group of pupils are working on an assignment where they are supposed to make a videogame with their micro:bit.

> "I get called over to a group of three boys, one of them has an orange t-shirt on. They want my help. I ask them what kind of game they would like to make. They explain to me that they would like to make a labyrinth that you are supposed to navigate. You will die if you touch the walls. I think for myself that that is a pretty ambitious project. I instruct them to start with moving a central character around and that they can make the maze afterwards." (Fieldnotes Solby Skole, September 18th, 2019).

This passage relates to creativity with technology, as well as several aspects of computational thinking. What makes this situation interesting is not only what the students do or say, but also what they are not yet able to do.

> "The children articulate a creative vision for how their video game is supposed to be. They can abstract the essential mechanics behind their game, but they struggle with programming it for their micro:bit. Algorithmic thinking and defining problems for computation are clearly still hard for these children." (Analytical memo written during analysis).

There is a richness to these foundational learning processes, where children are still grappling with new ways of thinking and creating, that is not captured by a codebook that strictly adheres to theory. When children are learning the basics, it is hard to find instances that live up to the theory. Even though the pupils in my investigation cannot yet autonomously go from problem to solution by means of a design process for example, there is still learning taking place that can help children achieve goals related to computational empowerment in later stages. In the next section I will present different moments of foundational learning that are discernable in the data.

Three moments of foundational learning

Of all the codes, “technology comprehension”, “creativity with technology”, “self-determination”, and “defining problems for computation” were the most frequently coded and occurred most frequently alongside other codes. Most assignments or learning were either focused on the aforementioned aspects or used these aspects as a foundation in order to develop other competencies, like engaging in design processes, investigating problems, or employing a socio-technical perspective. Because of their central position in relation to the data, they also became central connecting elements in the theory of foundational learning processes for computational empowerment that I will present and argue for in this chapter.

The distribution of codes over the empirical material suggests a temporal relationship between the different codes. First the pupils are provided a foundation in technology comprehension and programming, a first “moment of foundational learning”. Once pupils have achieved a certain level of skill and familiarity, they put this foundation into practice and exercise creativity and independent thought relating to technology. This entails forming their own opinions and ideas about technology and realizing these, as well as engaging with other people’s ideas and formulating or creating alternatives. This constitutes the second moment of foundational learning. In the third moment of foundational learning, when pupils are comfortable with creating technology and correspondingly show greater technological self-determination, they use their new knowledge and skills in design processes that seek to solve real world problems through creativity with technology. As will become clear, while in the data the relationship between these three moments of foundational learning is linear, it is uncertain if in other cases these moments of foundational learning have the same order or relationships to each other. Had there been such certainty, I would have termed these moments “stages of foundational learning” instead. So, the reason for calling the moments of foundational learning “moments” is to not create the impression of a certain and fixed linearity where there possibly is none. See figure 9 for an overview over the three moments of foundational learning that became apparent from the empirical material through interaction with this study’s theoretical framework, in the form of the codebook.

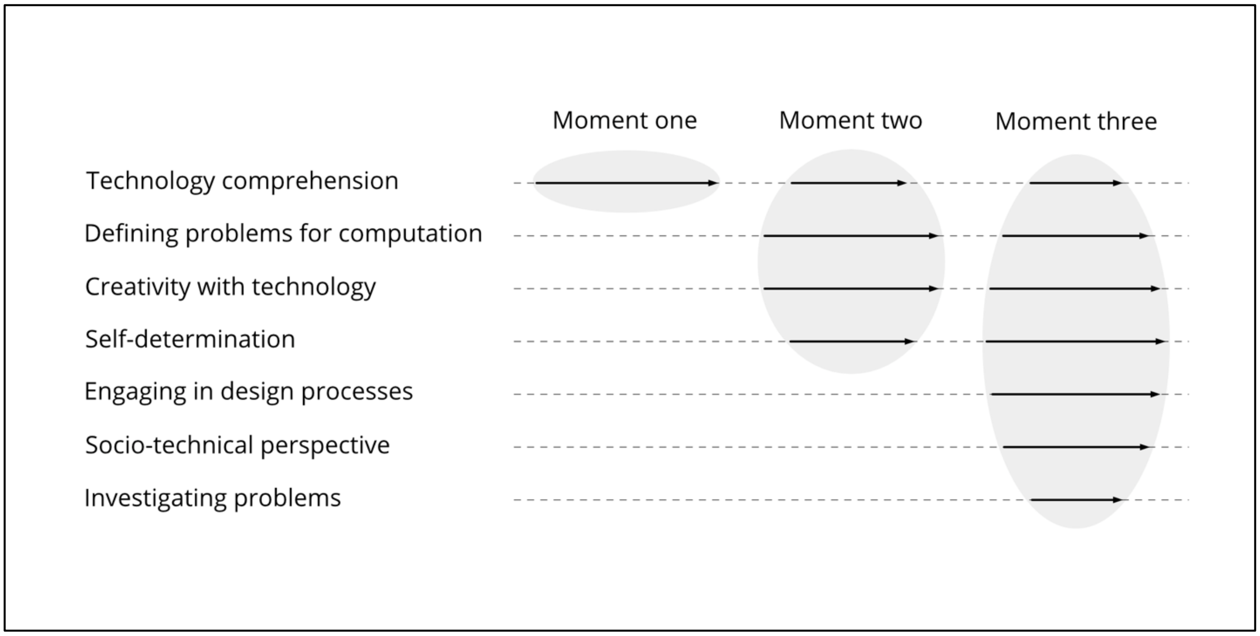

Figure 9: The pupils' general development (from left to right) in relation to the seven codes mentioned in this section (mapped over the three moments of foundational learning).

Moment one: learning to program and understand code

As mentioned, the first learning moment (abbreviation of moment of foundational learning) I have observed builds a foundation in technology comprehension and programming. In the data, this moment is typically characterized by assignments where children copy code from an answer model in Makecode and try out what it does on their micro:bit.

> "The teacher tells the kids that they can either make dice or that they can make a calculator. The teacher asks the class who wants to do what. Most kids want to make the calculator, so she shows the answer model of how the code is supposed to look on the smart board. (...) At some point most kids have made the easiest version of the calculator. Now, the teacher puts step two on screen. Here the kids have to use buttons in order to control the input numbers that the calculator is supposed to add to one another." (Fieldnotes Langeå Skole, September 23rd, 2019).

> “The teacher gives an introduction of what they are going to be doing. She shows them a video that explains radio signals and how to make a code that the children can use to send radio messages to each other.” (Fieldnotes Solby Skole, September 4th, 2019).

Copying code from an answer model sounds deceptively simple, but children in this moment often need help in order to find the right bricks and piece them together correctly.

> “I walk over to the two fourth graders. They are making a coin toss code. They have made two if-statements that do not have any ‘if’s’ in them. I help them by setting the interface to Danish and I help them make if-statements that work. I ask them if they think that working with micro:bit is hard. They say that they think so.” (Fieldnotes Stillested Skole, September 6th, 2019)

> “I help some kids with making sure that ‘on button pressed’ is set to different buttons. Some kids have trouble understanding why makeCode indicates an error when they have two ‘on button pressed A’ bricks in their code. I explain the kids why that is, and I help them fix the error. (Fieldnotes Langeå Skole, September 23rd, 2019).

In this learning moment children are working to overcome what I call a “correct-incorrect” mentality. Because they are afraid to make mistakes, they are often not willing to experiment with programming for themselves, instead they will ask their teacher, me, or a more advanced student for the *correct* answer. In the first example of this behavior a class is making a rock-paper-scissors game and a pupil is in doubt about how the icons are supposed to look.

> “11:54 - A girl asks how she is supposed to make a scissor. The teacher shows the class how they could make the icons. She says that the kids are free to make the icons as they like them themselves. (...) 11:57 - A boy and a girl ask me how they are supposed to make a scissors icon.” (Fieldnotes Ådal Skole, September 10th, 2019).

The next example is from the class where children had to program a basic calculator based on an answer model.

> “A girl in the corner asks for my help. I try to help her along, to have her figure it out herself. Every time, she says that she does not understand and

> crosses her arms over one another. I get the feeling that she wants me to do it for her. I tell her that I will not do it for her, but that I am willing to help her. I give her a hint for how she is to proceed. She says that she still does not understand. I tell her to take some time to think about it." (Fieldnotes Langeå Skole, September 23rd, 2019).

In reality there is not one right answer. There are many different ways in which a particular project can be coded. The teachers I have been in contact with commented on this behavior by underlining the importance of teaching their pupils to make mistakes and fostering a pro-active, curious, and experimenting attitude in them.

> "Children need to learn to make mistakes. She says that there is a difference between how curious different classes are. How pro-active they are willing to experiment with code. She says that luckily the class has not given up yet." (Fieldnotes Ådal Skole, September 10th, 2019).
>
> "Many of [my students] have the tendency, when it is difficult, to want a solution right away. I want them to try and explore the problem a bit before they look at the answer model. And of course, if they really could not find a solution, then they have gotten the solutions. However, this about getting them to try and experiment towards a solution. What works? What does not work? What if we try something else? And see if [Ultra:bit] can make them better at that, so they do not get so frustrated." (Teacher interview, Solby Skole, quote translated from Danish).
>
> "[My students] have also learned that something that looks hard maybe is not so hard after all. They have maybe discovered that [programming / creating with technology] is not so impossible to get started with. They have gotten better at saying: 'I will give it a shot'. They have lost that anxiety of working with technology. 'Now I will connect these things and it has to work'. That is gone. They are willing to try something out and see what happens." (Teacher interview, Dronning Margrete Skole, quote translated from Danish).

In this first moment of foundational learning, children also are led to understand the connection between the code they compose on their computers and the behavior of the micro:bit in the physical world, when they have uploaded their code to it. They have to build a connection between the abstract and the physical

(Katterfeldt, Dittert, and Schelhowe 2015). In the classes I have observed, this usually happened in the form of play.

> “I have now helped many kids. I notice that a significant amount of them has left the classroom. I find out that they are in the adjacent room. I walk over to the other room. They are doing some kind of tournament with their rock-paper-scissor-bits. They all shake simultaneously, then they have to go stand over to the corner that fits with the icon their micro:bit shows. Rock, paper and scissor all have their own corner. The kids standing in the corner with the fewest other children, get eliminated from the tournament.” (Fieldnotes Ådal Skole, September 10th, 2019).

> ”I follow the teacher out of the classroom. In the big hall, I see most kids from the class. They are playing and trying their creations out. Some kids are playing ping pong with micro:bits connected to their ping-pong bats. Another boy is running laps though the hall with a step counter taped around his leg. I talk with the second teacher that has joined us halfway through. We talk about how important it is that the kids are trying their creations out. Now they have to opportunity to test their work and to make adjustments. To apply what they have made to a real-life context in a way.” (Fieldnotes Langeå Skole, September 23rd, 2019).

The teachers I have interviewed have also underlined the importance of a tactile element when teaching children programming.

> “I like the programming part as well, because you can concretely take some elements and build something with it. This way of programming with bricks. [The pupils] can directly go form programming to having something concrete that works. That I think is super cool.” (Teacher interview, Lykkesten Skole, quote translated from Danish).

> “They both need to reflect on everyday life and learn about the technologies that are all over the place, but they also need that basis, to understand something about programming, to understand what it means to program. I think that Ultra:bit is a sensible tool for this. The best tool I have tried in any case. I have tried many like Skratch. I think that it requires too much understanding. With the micro:bit even the young kids (9-10 year old’s) can make something that they can show. Something they can go around and show to each other. There is this tactile quality, they can take it with them on

> their little board (micro:bit) and show it to each other. That is really good." (Teacher interview, Stillested Skole, quote translated from Danish, clarifications added).

Trying out creations also happens in later moments of foundational learning, and presumably also in more advanced forms of computational empowerment education. Trying out creations is important for finding mistakes in code or electric circuits, but also gives a sense of accomplishment. It is, however, in the first learning moment that children discover that what is coded on the computer gets transferred to the micro:bit, which then determines how it will behave in the physical world.

Moment two: creating with technology

In the second moment of foundational learning children apply basic programming skills and technology understanding in the creation of new projects. Here, children exercise their creativity and independent thought in relation to technology. In the data, the transition to the second moment is apparent in that children start to adjust or alter code they have copied. In the following example a girl has changed the rock-paper-scissor code so that she herself can choose which icon will be shown, instead of a random one appearing.

> "I ask a girl how she is doing. She shows me that she has made a rock paper scissors game. She has made it so that each button triggers a different icon." (Fielnotes Langeå Skole, September 23rd, 2019)

In the next example a boy has made alterations to a code he got from a friend.

> "I observe that a boy with a red shirt on already has a bunch of code on his screen. I remark that he already has a lot. He shows me this game that he had already made. You are a dot on the screen. You can move up and down. You are supposed to avoid obstacles, or else you lose. Some other boys in the room call it flappy bird, which is a mobile game that was notoriously difficult to complete. The red boy explains to me that he has shared his game with the other boys. One of the other boys says to the boy in the red shirt that he should speed up his game, like he has done. The other boy has made alterations to the red shirt wearing boy's game." (Fieldnotes Solby Skole, September 18th, 2019)

In this moment, children start working on their own projects. The teachers, who were educating in the creativity with technology moment, gave their pupils assignments that encouraged them to create something from their own imagination, sometimes within the bounds of a particular application or context.

> ”The teacher arrives. She asks me if I am ready for round 2. I reply that I am. I ask her what is on the programme today. She tells me that the kids need to try to make a computer game. They will not get the answer model to begin with. The teacher does not know how far the kids will get. She has the answer model to a rock, paper, scissors game in case it is needed.” (Fieldnotes Solby Skole, September 18th, 2019).

> “The teacher has divided the kids up into 4 groups each consisting of three teams. There are 4 groups, because she has 4 CFU boxes with external components for the micro:bit. Each group is supposed to make a plant watering machine and two other projects with water. Each group has to hand in three assignments, this corresponds with the three teams that each group has. The teacher says that the assignments have to do with water and that the kids have to demonstrate creative thinking.” (Fieldnotes Dronning Margrete Skole, October 10th, 2019).

> “Yesterday I received an email from the teacher. He explained me that the kids have gone through the introductory course of Ultra:bit last year, but that they have not worked with it since. Today they are supposed to use micro:bits for making a haunted basement for this year’s Halloween party.” (Fieldnotes Bakkeby Skole, October 22nd, 2019).

In this moment of foundational learning, children learn how to structure their ideas in such a way that they can code it for their micro:bit. They have to define problems for computation, abstract, and think algorithmically. In the data there are many instances of children that need help to structure their projects, because they do not know how to get started.

> “The two girls working on the eyes that follow visitors , work independently after I have given them some basic explanation for how they are supposed to code their project. I have to help them past an obstacle once or twice, but they surprise me with their ability to figure it out without help.” (Fieldnotes Bakkeby Skole, October 22nd, 2019).

> “I help a group of two boys make a cookie clicker game. I had no idea what that was. They showed me that it was a game where you click on a cookie to get points. It makes no sense to me whatsoever, but I help them make it. It is really easy to make. You get a point for clicking on A. You show the amount of points you have with B. You reset the game with A+B. The boys are surprised by how easy that was to make. They laugh about it. They show it to their friends.” (Fieldnotes Solby Skole, September 18th, 2019)

As the above examples illustrate, once I helped the children structure their project, they could code it themselves with relative ease or they were surprised by how easy it is to make. Children in the creating with technology moment can generally imagine projects they would like to make with their micro:bit and formulate how they would like to further develop their project, if they are not satisfied. However, creating something without an answer model is generally still too hard to accomplish without help. Apart from needing help with structuring their ideas, they often lacked the technical knowledge and skills to use the micro:bit’s more advanced features, such as sensors, external components, and radio transmissions.

> “The boys show me that their pump works. They want to add a potentiometer to control how intensely the pump should pump the water. I show them how to read the orientation of the potentiometer and how to send that value to the other micro:bit. I give them a little programming lesson about how you use the radio functionality of the micro:bits.” (Fieldnotes Lykkesten Skole, September 20th, 2019)

> “I helped some girls program an alarm with a button and a speaker. They want the alarm to go off when someone lifts an object that was resting on the button. I help them make the code that sends a radio message when something is lifted off the button.” (Fieldnotes Lykkesten Skole, September 20th, 2019)

> “I return to the boy and the girl that I helped first. I help them make a project that has a 20 percent chance of triggering a water cannon when you press a button. The girl came up with the idea.” (Fieldnotes Dronning Margrete Skole, October 10th, 2019).

These examples illustrate that growth in creativity with technology and computational thinking also requires growth in technology comprehension and programming. The excerpts of children creating or altering code that I have used in this section also point to development in self-determination. They do not blindly copy an answer model. Instead they come up with their own ideas. They can envision and communicate how they would like their technology or project to be. They can, furthermore, think of ways to improve their projects or develop them further. All this demonstrates that they have begun to think beyond established technological solutions. They are willing to explore alternatives and create technology themselves. What does self-determination and independent thinking in relation to technology entail if it is not about envisioning alternatives to the established and realizing one's own technological ideas? While many children in this learning moment, of course, still need a lot of help to make their technological ideas a reality, sometimes they can work surprisingly independently, like the girls in the following passage.

> "Further down in the same room two girls call me over. They have made a text-based game. You are supposed to answer a math question before the timer runs out. When the timer runs out, it displays the answer." (Fieldnotes Solby Skole, September 18th, 2019)

Moment three: design processes and real-world problems

The third moment of foundational learning for computational empowerment education became apparent from passages in the data that had a high coding density and were coded under many different aspects of this study's theoretical framework. These passages would often be a nexus for codes related to creativity with technology, computational thinking, design thinking, socio-technical perspectives, Bildung, and technology comprehension. The third learning moment is versatile and can facilitate learning related to the aforementioned concepts depending on the emphasis of a particular assignment. The assignments in the data that fit with this moment of foundational learning required pupils to engage in a design process in which they create a technology to solve a real-world problem.

> "[The teacher] tells me that the children are working on solving problems at the school. (...) The kids have to define their own problems around the school. They have to make a solution to the problem in the form of a prototype. The prototype has to use a micro:bit." (Fieldnotes Stillested Skole, September 5th, 2019).

> "The teacher tells me that they will be working on "knæk klima koden", which is a competition where kids have to come up with solutions to solve the climate crisis. The teacher has borrowed a box with extra components from CFU. (…) He tells one of the kids that he is not supposed to just program today. They are supposed to find a problem, think about how they can make it better and then make a prototype with micro:bit. The teacher has a document that describes what steps the children are supposed to take." (Fieldnotes Lykkesten Skole, September 20th, 2019).

Like in the second learning moment, children need help structuring the assignment and programming more advanced functionality. This moment also comes with its own challenges though. In Lykkesten Skole children had a hard time handling the complexity of creating a technology that is supposed to help solve a global problem like climate change. To illustrate this, I will give an example of two girls.

> "I try to help two girls get started. But when I ask them how I can help; it does not seem like they really know what they need my help for. (…) The two girls that I have gone over to before are once again in front of the queue. I feel guilty when I walk over to them. I assume that they would rather have their teacher's help. They need to find a problem to work on. I show them where they can find some examples to work on." (Fieldnotes Lykkesten Skole, September 20th, 2019).

At the time I thought that their behavior can be explained by that they would rather have the help of their teacher. Their teacher had a different idea.

> "We also talk about the two girls who asked for help and did not really explain to me what they needed help with. I say that I think that it might be, because they would rather have his help. He says that that is not the case. He thinks that the girls just really do not know how they should start. He thinks it is because the girls are unsure about what to do." (Fieldnotes Lykkesten Skole, September 20th, 2019).

When I interviewed the teacher a few days after, he reflected further on why his pupils were not able to complete the assignment.

> "When you were there that day, there were some that completely lost hope, because it became all too abstract, this aspect about saving the climate." (Teacher interview, Lykkesten Skole, quote translated from Danish).

> “They could not at all do it, coming up with an idea and programming something that was not in reality. This part about connecting an idea or concept to something they had to program in order to save the world, that was simply too large for them. (…) The aspect about that they had to save the world took up so much space for them. This classical anxiety about the outside world. They get scared of everything in the world and they shut down because of it. And then they could not program. (…) When I removed the ‘save the world’ aspect, they were able to program the same things they could not before.” (Teacher interview, Lykkesten Skole, quote translated from Danish).

This example illustrates that investigating a problem, engaging in a design process, imagining a solution, and building a prototype can be too many tasks for the children to relate to on the outset. It had a paralyzing effect on the children at Lykkesten Skole. However, once the children were free to forget about climate change and just build something they wanted to make, they were able to create. At Stillested Skole they did have success with their approach. While some groups had more sophisticated results than others, all groups could present a problem, their solution, and demonstrate the functionality of their prototype. Here follow three presentations given by pupils at Stillested Skole.

> “The girls start. They wanted less pizza boxes. They say that their prototype in reality would not use a windmill, because they are way too big. Instead it would probably be better to use solar energy. They walk through their code and explain it to the class. Then they give a demonstration like they gave me on a large table out on the hallway. ‘The windmill on the robot first made 100 rotations. Then the robot drove about 2 meters in one direction. Then the windmill made another 50 rotations, after which the robot opened the door to the oven’.” (Fieldnotes Stillested Skole, September 6th, 2019).

> “Next up are the center boys. The problem that they identified is food wastage at school. They then show their design process. They explain how they made their prototype out of cardboard. They give a demonstration of their prototype in front of the class (it works well). The teacher wants them to show the code. One of the boys runs out of the room to get the computer. The boys never showed the code, instead they are trying to recall how they coded their prototype. They cannot totally explain how it worked.” (Fieldnotes Stillested Skole, September 6th, 2019).

> "Then come the red+blue boys. They have a trash collecting robot. They say that it is supposed to work like a trash truck. They show the code. (...) The teacher asks the boys why they used the light sensor on the micro:bit. The boys try to explain that it was supposed to detect trash. Ah, says the teacher, it was supposed to be a camera. The boys say yes." (Fieldnotes Stillested Skole, September 6th, 2019).

A difference between the approaches at Lykkesten and Stillested Skole is that the children at Stillested had to investigate and solve problems at their school, in contrast to an ill-structured and wicked problem like climate change. A local problem is in all likelihood easier to relate to. However, since I only have two cases of stage three foundational learning, I am not sure what other factors may play a role in Stillested's success or Lykkesten's problems. Perhaps the children at Stillested simply had more experience, and perhaps the children at Lykkesten were not yet ready for this assignment. It would have been easier to compare the two schools if I had been present at the start of Stillested's assignment. It is entirely possible that the children at Stillested also initially struggled with the many aspects of their assignment. Whichever the case, most of the children at Stillested demonstrate that they are able to engage in a basic design process and that they can navigate the interaction between a social problem and a particular technology, in addition to applying the focus areas of the first and second moment of foundational learning.

Transition to advanced computational empowerment education

Although children have come a long way, I have no observation data of children reaching the point where they can explicitly reflect on the role that technology plays in society and individual lives. Furthermore, as the example of Lykkesten Skole illustrates, it is potentially still hard for pupils in the third learning moment to relate to ill-structured and wicked problems. Lastly, a reflective metacognition about the impact or permissibility of one's own creations was also found lacking in the data. The following example illustrates absence of such metacognition.

> "I ask the boys if they have any ideas for projects they would like to make with micro:bit in the future. One boy says that a 4th grader had the idea to hack into the teacher's computers. Another boy, clearly inspired by this idea,

> suggests that it would be cool to use the micro:bit to infect computers with a computer virus.” (Fieldnotes Lykkesten Skole, September 20th, 2019).

Depending on the emphasis of education in the third moment, children may not have engaged with certain dimensions of computational empowerment when they transition from foundational learning to the computational empowerment education envisioned by Dindler, Smith, and Iversen (2020). However, this does not necesarrily mean that the moments of foundational learning are lacking. Ultimately, children are supposed to reach the goals set by computational empowerment through its current model for education, in which they work on constructing and deconstructing technology (Dindler, Smith, and Iversen 2020). The three moments I have proposed only provide a foundation.

As the three moments of foundational learning are the only ones I could discern in the data, what I can contribute with beyond these is limited. However, the interview with the teacher from Stillested Skole provides some insight into the transition from foundational learning to the point where children can deconstruct technology by reflecting on the ethical impications of technology and employing a socio-technical perspective.

> ”There are a lot of interesting discussions you can begin to have about a particular technology. The most important premise for that we can have these conversations is that the children have some knowledge about it, so they can have the discussion based on professional knowledge. I think that especially in higher primary and lower secondary education children need to acquire this professional ballast, so they really can reflect and put things in perspective when they are older”. (Teacher interview, Stillested Skole, quote translated from Danish).

Even though children potentially have not yet engaged with the socio-technical dimension of computational empowerment after the three moments of foundational learning, they do get a knowledge basis that can facilitate this later on. When asked if his students ultimately were able to critically reflect on technology and employ a socio-technical perspective, Stillested’s steacher responded the following:

> “Yes, if I talk to them. Especially with the sixth graders I could have a little conversation about these ethical questions. I have used self-driving cars as an example, because someone has to programme what they do. The ethical

dilemmas relating to this I could begin to discuss with small groups of sixth graders (approximately 12 years old). Not with students from fourth grade (approximately 10 years old). I would use the example that if the car continues straight ahead and then to the left, then it would run over two people, if the car goes in another direction the driver will die. What choice should the car make? There are some adults that make these decisions. The car cannot think for itself, so we have to make these decisions beforehand. These ethical dilemmas stem from our dependence on electronics. Some decisions will be taken for us. What these decisions will be is not determined by the technology. Instead we are forced to make these decisions beforehand. And these discussions are interesting, because there is not one right answer. (…) But that is also the furthest that I have come with my pupils." (Teacher interview, Stillested Skole, quote translated from Danish, clarifications added).

"And then I have also talked with them about some smaller local matters. What if we use a camera for surveillance? More practical matters. [My pupils] are of course all different, but the goal is that all of them get to the point where they say: 'Okay, we are using technology. There is always ethics inolved.' The surveillance camera is supposed to catch a lot of criminals, but it is also a hindrance to another person's freedom, it restricts their freedom. That is a consequence of it. It is not because one thing is right or wrong. It means that we have to try to reflect: What is the right way?" (Teacher interview, Stillested Skole, quote translated from Danish).

The quotes illustrate that after I have visited this school, the teacher and his pupils have achieved ethical reflection and socio-technical perspectives beyond the scope of the three moments of foundational learning. This in turn supports that the foundational learning I have presented can facilitate critical reflection at a later stage.

Discussion

In this chapter I formulate answers to the research question and sub-questions. Afterward, I present several methodological reflections. Lastly, I reflect on what is still uncertain or unknown about the findings I presented in the previous chapter.

Research questions

Firstly, I will return to the sub-questions and the main research question that I have presented at the beginning of the method chapter.

To what extent are all dimensions of computational empowerment put in practice by teachers that participate in Ultra:bit? And how do the pupils that participate in Ultra:bit education at school develop toward computational empowerment?

In the observation data, the teachers are at the various moments of foundational learning that I have presented in this chapter. Some teachers were building a foundational technology comprehension and teaching their pupils basic programming. This corresponds to partial development of the "programming and computation" dimension of computational empowerment, which, as established in the review of educational concepts, covers skills and knowledge relating to programming and computational thinking.

Other teachers had their pupils exercise their independent thought and creativity with technology. This demonstrates progress in the "creativity with technology" and "Bildung" dimensions, in addition to further progress in the "programming and computation" dimension. The "creativity with technology" dimension covers design thinking, as well as the creativity and attitude required to become a producer of technology. The "Bildung" dimension focusses on forming individuals, cultivating their humanity, and empowering them to live meaningful lives in a society permeated by digital technology (see the review of educational concepts).

Lastly, one school had successfully engaged in a design process that solved problems in their school with technology. Their teacher has reported that the 6th graders at this school later were able to reflect on the ethical and social aspects of various technologies. This would be indicative of growth in all dimensions of computational empowerment, including the "socio-technical perspective" dimension, which examines technology’s impact on society, its role in individual lives, and the values that are embedded in it (see the review of educational concepts).

How can computational empowerment in all its dimensions be applied in educational initiatives aimed at primary and lower secondary school education?

The analysis has shown that the most appropriate answer to the research question is the following. In order for children in upper primary and lower secondary education to get to the point in which they can be taught in all dimensions of computational empowerment, they need to pass three moments of foundational learning. In the data, pupils firstly build a rudimentary technology understanding and acquire basic programming skills. In more complex tasks they can relate this foundation to the exercise of their independent thought and creativity in connection to technology. This is done by creating technological projects after their own imagination. In the most advanced assignments I have observed, the children learn to apply their technology comprehension, independent thought, and creativity in a design process that seeks to solve a real-world problem with a new technology or prototype. When all three foundational moments become part of their experience, children potentially have a basic familiarity with all dimensions of computational empowerment, which prepares them to participate in more advanced forms of computational empowerment education, such as those envisioned by Dindler, Smith, and Iversen (2020).

The answer I just outlined contributes to the further development of theory related to computational empowerment and Bildung, as well as the state of the art in Fablearn, Interaction Design and Children, Participatory Design, and Child-Computer Interaction.

More explicitly, the results of this thesis contribute to the body of knowledge related to how computational empowerment can be applied in education and what schemes computational empowerment needs in order to assess children’s development towards it (Iversen, Smith, and Dindler 2018; Eriksson et al. 2019; Dindler, Smith, and Iversen 2020). In addition, this study contributes with new knowledge about how a younger age group (10-12 in comparison to children between the age of 11 to 15 studied in (Iversen, Smith, and Dindler 2018)) take their first steps towards computational empowerment.

This thesis' primary concrete contribution to computational empowerment is the moments of foundational learning that provide grounds for understanding what steps pupils in upper primary and lower secondary education take in order to reach the point where they can participate in computational empowerment education as it is currently understood in theory. This is relevant as the empirical material illustrates how practices at upper primary and lower secondary school do not live up to the theoretical ideal, as formulated by Dindler, Smith, and Iversen (2020). The moments of foundational learning provide support to navigate and understand the tensions between computational empowerment education in theory and in practice for this younger age group.

Not only does the thesis make new additions to theory, it also reports successes and challenges in the application of computational empowerment and in pupils' learning. I have shown how teachers have made Ultra:bit their own, which in its goals is inspired by computational empowerment, and how they have put it in practice in their classes. The moments of foundational learning do not only document learning, but indirectly also how teachers have approached teaching Ultra:bit and what challenges they encountered. The moments also demonstrate how pupils at the schools I have visited have already achieved some of the goals that computational empowerment has set for education to a basic degree. Depending on their progress, children have gained a foundational technology comprehension, learned basic programming, developed their creative and independent thinking abilities in relation to technology, learned how to engage in a rudimentary design process, practiced investigating problems, and trained a socio-technical perspective.

The results presented in this work are not only relevant for computational empowerment, but also for Bildung. The moments of foundational learning also show development in children's self-determination in relation to technology. Children outgrow the "correct-incorrect mentality" and they learn to investigate a problem or challenge for themselves. They develop their ability to think independently; to think of their own solution rather than the teacher's or mine. They learn to not take technology at face value, but instead they exercise their ability to conceive of alternatives and to realize these. These results are potentially interesting both for classical Bildung theory, like that of Klafki (2012), but also approaches for Bildung that are focused on digital technology. Growing children's ability to conceive of alternatives to existing technology and teaching them to create their imagined technologies resonates with Katterfeldt, Dittert, and Schelhowe's (2015) concern for self-efficacy, which entails the ability to act autonomously in a digital world and to produce technology rather than only consuming it.

Furthermore, the moments of foundational learning and computational empowerment education in general prepare children for challenges that they will face in the future. As society will presumably become increasingly digitized through their lifetimes, a concern for their Bildung demands that children need to be equipped with the tools to handle challenges related to this (Klafki 2012). Computational empowerment aims to teach children a form of 21st century reading, by which I mean deconstructing technology, and writing, which corresponds to constructing technology (Dindler, Smith, and Iversen 2020). Children develop a kind of digital literacy that will hopefully prepare them for the challenges of living in a thoroughly digitized society.

At more advanced stages of computational empowerment education children also learn to reflect on society's problems related to technology. Furthermore, they are given a foundation for reflecting on the morality of technology, certain applications of it, and their own behavior in connection to technology. Moreover, children are given a new avenue for creative expression. Children learn to express themselves though programming, electronics, and potentially other technologies often used in digital fabrication, like 3D printers and laser cutters. All the examples given in this paragraph are classical concerns for Bildung (Klafki 2012), which find their expression in education for computational empowerment. These are all small parts of an answer to what constitutes an educated and cultivated human being in contemporary society, which, according to Biesta (2002), is the central question in the Bildung tradition.

As mentioned, I think that the results of this investigation are potentially interesting for researchers in the fields of Fablearn, Interaction Design and Children, Participatory Design, and Child-Computer Interaction in general. As the foundational learning processes related to computational empowerment, Making, and computational thinking are similar in that in all of them children need to learn to understand technology, learn basic programming, as well as creativity with technology, the foundational learning processes presented in this thesis might be relevant for other educational approaches and foci. Furthermore, my results in relation to what children struggle with at different stages of foundational learning might be equally interesting. Perhaps researchers dedicated to other approaches find that the children they study struggle with similar issues. This could contribute to a better collective understanding of children's challenges when learning about programming, creativity with technology, and technological self-determination among other things.

This thesis can also contribute to some direct calls for research made by scholars in the aforementioned conferences and journals. Firstly, I hope to have contributed to growth of the scholarly understanding of design and empowerment aspects in Making education for children, which Kinnula and Iivari (2019) identified as limited in current research. As my investigation reports on children's development in relation to design thinking, computational empowerment, and Bildung in the context of an education project that integrates Making practices in upper primary and lower secondary education, my thesis is well positioned to contribute to filling this knowledge gap.

In addition, my thesis illustrates how children's learning differs in three moments of foundational learning. These three moments became apparent from children's longer-term engagement in a Making inspired education initiative, specifically meant for integration in formal education. As such, my thesis can contribute to Tuhkala et al.'s (2018) and Ventä-Olkkonen et al.'s (2019) call for research into longer-term Making education initiatives in a school context. I hope that my thesis can provide insight into how longer-term Making education initiatives impact children's development, for instance. This can, in turn, be compared to the many examples in the CCI-community of short-term and out of school Making education activities (Tuhkala et al. 2018; Ventä-Olkkonen et al. 2019).

Lastly, although it is not the focus of my study, this thesis' findings also illustrate the practices of teaching and learning related to Making taking place at several schools. Using ethnographic methods, such as participant observation and informal interviews, I have immersed myself in the aforementioned practices, in order to gain an emic perspective on them. I have also illustrated what takes place in these Making practices from the theoretical perspective (etic) of this study. As such, my work is potentially interesting for the research agenda formulated by Ventä-Olkkonen et al. (2019), which calls for studies of an ethnographic nature that document what goes on in Making practices at schools.

Methodological reflections

A first methodological reflection pertains to the way I have selected schools. When searching for participants for this study, the way that I incentivized teachers may have caused more teachers to participate that were new to teaching programming and Ultra:bit than teachers that were more advanced (van den Boogaard 2019). In the emails I sent to teachers, I offered that I could assist their pupils in their assignments and answer their questions in relation to programming and electronics, in exchange for allowing me to conduct participant observation at their Ultra:bit classes. Since I have experience with programming micro:bit myself, because I have created programming projects for Ultra:bit as part of my study job at DR Skole, I could potentially be a big help to teachers that were insecure about programming and electronics. Teachers that already had more experience with this, would presumably not get as much out of my help. This could explain why I had difficulties with finding more advanced classes. The lack of advanced schools included in my study can make the last moment of foundational learning less representative than the other moments, as it is only based on two schools.

My contact to the pupils and who of them I chose to talk to is another issue that needs consideration. As described in the method chapter, during my participant observation at schools, I spent a considerable amount of time helping students with their assignments and answering their questions. While there were times where I could walk around and offer my help, most of the time there were so many pupils that wanted help, that I could only help those that proactively sought me out. As it was important for me to build rapport with the pupils prior to interviewing them, I would often return to those pupils that I had helped most during the day. In this way, the pupils effectively selected themselves for the study, instead of me. This could have skewed the impression I got of children's development. I potentially mainly saw the development of those children that were engaged and wanted my help to learn or create, and conversely missed the experiences and development of children that were less engaged. To counteract this influence, I have made sure to compare the development apparent in my fieldnotes to the development that teachers reported.

A third concern pertains to my interpretation of theory relating to computational empowerment, computational thinking, design thinking, and Bildung. The validity of the results of my study only extend so far as my interpretations of the theory underlying the codebook are valid. I have done my best to consult multiple sources relating to each educational concept from relevant conferences and journals, so as to not favor any individual perspective and achieve a nuanced understanding of each concept. Furthermore, I have aimed to present and process the theory related to these concepts as faithfully as possible. In the case of computational empowerment, I have given myself license to propose a new overview over the concept's dimensions though. To make sure that researchers with a different interpretation or perspective on the theory can draw their own conclusions, I have made this study's data available in the appendices.

Fourthly, the limited time I have spent in the field doing participant observation influences my findings as well. The majority of the schools I have done participant observation at, I have visited only once and there is only one school I have visited more than twice. There was unfortunately a limited amount of schools that worked on Ultra:bit in the months that I could conduct participant observation and were willing to receive me. The schools that did only had limited classes with Ultra:bit scheduled or had already done a number of classes before I joined. Had I been able to find more schools or conduct participant observation at more classes at the schools I have visited, the quality of my study would in all likelihood have been improved markedly for several reasons. Firstly, had I been able to build up more rapport with pupils and teachers, then they would in all likelihood have been more willing to help me with my investigation and allowed me greater insight into their thoughts and experiences relating to Ultra:bit. In addition, more time in the field would also have allowed me to help and speak to more pupils, which in turn would have made my data more representative. Furthermore, I would have been able to observe and participate in more examples of moments of foundational learning, which would plausibly have resulted in a more nuanced and detailed understanding of these. More time doing fieldwork would probably contribute to greater quality in other dimensions of my study as well, though it is hard to anticipate exactly in what way. Suffice to say, that more time spent in the field could have benefitted this thesis.

Lastly, it is important to reflect on how the knowledge created in this thesis is situated; how my perspective, as a researcher, is partial and particular (Haraway 1988). Throughout the data gathering and writing for this thesis, I have had a student job at DR Skole, where I worked on micro:bit programming projects for Ultra:bit. Furthermore, when gathering my data, I was an intern at DR Skole. During my internship I worked on evaluating Ultra:bit. With my student job, my internship, and the semester projects I have written about Ultra:bit, I have seen and experienced the project from many different sides. I have seen the project from the perspective of a creator. I have had influence on the education material that is used by teachers and pupils. I have, during my participant observation at schools, taught children in programming and electronics and helped them with their questions. So, I have also played the role of the teacher. And lastly, I have investigated Ultra:bit, as a student and as an intern. One could argue that the fact that I have spent so much time involved in Ultra:bit and that I have experienced so many different angles of it, adds to my authority when writing about Ultra:bit. On the other hand, it might be difficult for me to divorce what I know about Ultra:bit from my experiences working for DR Skole, from what I am learning from teachers and pupils. It is possible that my own involvement in creating Ultra:bit caused me to develop my own understanding and opinions relating to it. This could have impaired my ability to fully immerse myself in the perspective of teachers and pupils. Whichever the case, it is probable that my experiences creating programming projects for Ultra:bit and my internship at DR Skole have influenced the work presented in this thesis. A completely objective researcher, who does not have a particular point of view, does not exist; every researcher sees the world from a particular perspective, and this colors our understanding (Haraway 1988). Nevertheless, a researcher, who does not have the same relationship to Ultra:bit, would in all likelihood have had a different perspective, and could have potentially drawn different conclusions. This is another reason why I invite the reader to examine the data I have gathered for themselves, so they can draw their own conclusions.

Uncertainties and limits

First and foremost, it is uncertain if the moments of foundational learning that I have observed are also identifiable in other cases and if they are put in practice in the same order by other teachers.

Secondly, as I only have data on a few classes, there is potentially much that can still be learned about the moments of foundational learning themselves. I do not think that I have seen, documented, and synthesized all that children learn and struggle with. Especially the design processes and real-world problems moment needs more investigation, as I have based this moment on only two classes, one of which had to drop their assignment by allowing their students to create freely, without constraints of a design process or a problem context.

The spaces between the learning moments I have identified are also uncertain. In all likelihood some children will be ready to pass to a next learning moment before some of their peers are. It is therefore conceivable that in a class you have children in two or more learning moments simultaneously. Facilitating learning at different speeds and levels creates challenges for teachers (van den Boogaard et al. 2018). Therefore, it would be interesting to gather more data about the moments of foundational learning and the spaces between them with special attention to the challenges related to having pupils in different moments in the same class.

Lastly, there is still little to nothing known about the transition from these foundational learning processes to computational empowerment education as it envisioned in current theory. Do the moments of foundational learning that I have proposed actually prepare children for advanced computational empowerment education? How is the initial learning in advanced computational empowerment education organized? Is there an overlap? Is there a gap between the moments of foundational learning and advanced education?

Conclusion

In this thesis I have documented my investigation into education for computational empowerment with Ultra:bit as a case. I was specifically interested in how computational empowerment in all its dimensions can be applied in educational initiatives aimed at upper primary and lower secondary school education. To answer this central research question, I found eight classes in different schools that were working with Ultra:bit, where I could do participant observation and conduct informal interviews with pupils and teachers. I supplemented the data gathered with five semi-structured interviews with teachers, whose classes I had visited. Afterwards, I analyzed the data using two rounds of coding, analytical memo writing, and several techniques to organize my coded data and visualize patterns, such as mind mapping. The first round of coding was done with a codebook based on theory associated with the educational concepts of computational empowerment, computational thinking, design thinking, and Bildung. For the second round of coding the codebook was supplemented with inductive codes that became apparent from the data.

After the analysis, it became clear that my study is better suited to contribute with three moments of foundational learning leading up to more mature forms of computational empowerment education. In the first moment children develop a foundational technology comprehension and learn basic programming. In the second moment children expand this foundation by exercising their creativity and independent thinking abilities in relation to technology. And lastly, in the third moment children use what they have learned previously to engage in design processes that seek to solve real-world problems with the creation of new technology.

To overcome the limits of this study that I am aware of, I would consider the following avenues for future research. Primarily, more investigation is needed to see if the moments of foundational learning are also apparent in other cases. Secondly, the learning moments in general, and the last stage especially, could use further research to achieve a more nuanced and complete understanding of what children learn and find difficult in each stage. Thirdly, the spaces between the learning moments are potentially interesting to study, because having pupils in more than one moment simultaneously can create challenges for teachers. Lastly, research is needed to study the transition from foundational learning to education for computational empowerment as it is envisioned in current theory.

Reference list

Allsop, Yasemin. 2019. “Assessing Computational Thinking Process Using a Multiple Evaluation Approach.” *International Journal of Child-Computer Interaction* 19 (March): 30–55. https://doi.org/10.1016/j.ijcci.2018.10.004.

Bernard, H. Russell. 2006. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. 4th ed. Lanham, MD: AltaMira Press.

Biesta, Gert. 2002. “Bildung and Modernity: The Future of Bildung in a World of Difference.” *Studies in Philosophy and Education* 21 (4): 343–351. https://doi.org/10.1023/A:1019874106870.

Bocconi, Stefania, Augusto Chioccariello, Giuliana Dettori, Anusca Ferrari, and Katja Engelhardt. 2016. “Developing Computational Thinking in Compulsory Education - Implications for Policy and Practice.” Science for Policy Report. Seville: EU Joint Research Center (JRC). https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/developing-computational-thinking-compulsory-education-implications-policy-and-practice.

Boogaard, Bas van den. 2019. “Ultra:Bit in Classrooms.” Student project. Aalborg University.

Boogaard, Bas van den, Ida Bruun Hougaard, Lasse Krejberg Møller, Jesper S.B. Rasmussen, and Sofia Ilieva Stancheva. 2018. “The Ultra:Bit Project: Discrepancies within the Ultra:Bits Performances in Its Networks.” Student project. Aalborg University.

Brennan, Karen, and Mitchel Resnick. 2012. “New Frameworks for Studying and Assessing the Development of Computational Thinking.” In *Proceedings of the Annual Meeting of the American Educational Research Association*, 1–25. Vancouver, Canada.

Brinkmann, Svend, and Lene Tanggaard. 2015. *Kvalitative metoder: en grundbog*. Kbh.: Hans Reitzel.

Carl, Nicole Mittenfelner, and Sharon M. Ravitch. 2018. “Interviews.” In *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation. 4 4*, edited by Bruce B Frey. SAGE Publications, Inc. http://sk.sagepub.com/reference/sage-encyclopedia-of-educational-research-measurement-evaluation.

Carlborg, Niklas, Markus Tyrén, Carl Heath, and Eva Eriksson. 2019. “The Scope of Autonomy When Teaching Computational Thinking in Primary School.” *International Journal of Child-Computer Interaction* 21 (September): 130–39. https://doi.org/10.1016/j.ijcci.2019.06.005.

Chalmers, Christina. 2018. “Robotics and Computational Thinking in Primary School.” *International Journal of Child-Computer Interaction* 17 (September): 93–100. https://doi.org/10.1016/j.ijcci.2018.06.005.

Christensen, Kasper Skov, Mikkel Hjorth, Ole Sejer Iversen, and Rachel Charlotte Smith. 2019. “Understanding Design Literacy in Middle-School Education: Assessing Students’ Stances towards Inquiry.” *International Journal of Technology and Design Education* 29 (4): 633–54. https://doi.org/10.1007/s10798-018-9459-y.

Chu, Sharon Lynn, Francis Quek, Sourabh Bhangaonkar, Amy Boettcher Ging, and Kumar Sridharamurthy. 2015. “Making the Maker: A Means-to-an-Ends Approach to Nurturing the Maker Mindset in Elementary-Aged Children.” *International Journal of Child-Computer Interaction* 5: 11–19. https://doi.org/10.1016/j.ijcci.2015.08.002.

CSTA, and ISTE. 2011. “Operational Definition of Computational Thinking.” https://id.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf.

Danmarks Radio. 2018a. “Didaktik: Gå ultra:bit med DR Skole.” https://www.dr.dk/undervisning_flash/ultrabit/didaktik.pdf.

———. 2018b. “Om BBC micro:bit.” DR. 2018. https://www.dr.dk/om-dr/om-bbc-microbit.

———. 2018c. “DR Ultra:bit Brief til producenter.”

Dindler, Christian, Rachel Smith, and Ole Sejer Iversen. 2020. “Computational Empowerment: Participatory Design in Education.” *CoDesign* 0 (0): 1–15. https://doi.org/10.1080/15710882.2020.1722173.

Eriksson, Eva, Carl Heath, Peter Ljungstrand, and Peter Parnes. 2018. “Makerspace in School—Considerations from a Large-Scale National Testbed.” *International Journal of Child-Computer Interaction* 16 (June): 9–15. https://doi.org/10.1016/j.ijcci.2017.10.001.

Eriksson, Eva, Ole Sejer Iversen, Gökçe Elif Baykal, Maarten Van Mechelen, Rachel Smith, Marie-Louise Wagner, Bjarke Vognstrup Fog, et al. 2019. “Widening the Scope of FabLearn Research: Integrating Computational Thinking, Design and Making.” In *Proceedings of the FabLearn Europe 2019 Conference*, 1–9. FabLearn Europe ’19. Oulu, Finland: Association for Computing Machinery. https://doi.org/10.1145/3335055.3335070.

Flores, Christa. 2018. “Problem-Based Science, a Constructionist Approach to Science Literacy in Middle School.” *International Journal of Child-Computer Interaction* 16 (June): 25–30. https://doi.org/10.1016/j.ijcci.2017.11.001.

Grammenos, Dimitris, and Margherita Antona. 2018. “Future Designers: Introducing Creativity, Design Thinking & Design to Children.” *International Journal of Child-Computer Interaction* 16 (June): 16–24. https://doi.org/10.1016/j.ijcci.2017.10.002.

Grizioti, Marianthi, and Chronis Kynigos. 2018. “Game Modding for Computational Thinking: An Integrated Design Approach.” In *Proceedings of the 17th ACM Conference on Interaction Design and Children*, 687–692. IDC ’18. Trondheim, Norway: Association for Computing Machinery. https://doi.org/10.1145/3202185.3210800.

Haraway, Donna. 1988. “Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective.” *Feminist Studies* 14 (3): 575. https://doi.org/10.2307/3178066.

Holst, Katrine. 2020. “Ny bevilling giver ultra:bit vokseværk.” DR. 2020. https://www.dr.dk/presse/ny-bevilling-giver-ultrabit-voksevaerk.

Humboldt, Wilhelm von. 2012. “Theory of Bildung.” In *Teaching As A Reflective Practice : The German Didaktik Tradition*, edited by Ian Westbury, Stefan Hopmann, and Kurt Riquarts, translated by Gillian Horton-Krüger. Routledge. https://doi.org/10.4324/9780203357781.

Iivari, Netta, and Marianne Kinnula. 2018. “Empowering Children through Design and Making: Towards Protagonist Role Adoption.” In *Proceedings of the 15th Participatory Design Conference: Full Papers - Volume 1*, 1–12. PDC ’18. Hasselt and Genk, Belgium: Association for Computing Machinery. https://doi.org/10.1145/3210586.3210600.

Iversen, Ole Sejer, Rachel Charlotte Smith, and Christian Dindler. 2018. “From Computational Thinking to Computational Empowerment: A 21st Century PD Agenda.” In *Proceedings of the 15th Participatory Design Conference on Full Papers - PDC ’18*, 1–11. Hasselt and Genk, Belgium: ACM Press. https://doi.org/10.1145/3210586.3210592.

Katterfeldt, Eva-Sophie, Nadine Dittert, and Heidi Schelhowe. 2015. “Designing Digital Fabrication Learning Environments for Bildung: Implications from Ten Years of Physical Computing Workshops.” *International Journal of Child-Computer Interaction* 5: 3–10. https://doi.org/10.1016/j.ijcci.2015.08.001.

Kinnula, Marianne, and Netta Iivari. 2019. “Empowered to Make a Change: Guidelines for Empowering the Young Generation in and through Digital Technology Design.” In *Proceedings of the FabLearn Europe 2019 Conference*, 1–8. FabLearn Europe ’19. Oulu, Finland: Association for Computing Machinery. https://doi.org/10.1145/3335055.3335071.

Klafki, Wolfgang. 2012. “The Significance of Classical Theories of Bildung for a Contemporary Concept of Allgemeinbildung.” In *Teaching As A Reflective Practice : The German Didaktik Tradition*, edited by Ian Westbury, Stefan Hopmann, and Kurt Riquarts, translated by R. MacPherson. Routledge. https://doi.org/10.4324/9780203357781.

Lüth, Christoph. 2012. “On Wilhelm van Humboldt’s Theory of Bildung.” In *Teaching As A Reflective Practice : The German Didaktik Tradition*, edited by Ian Westbury, Stefan Hopmann, and Kurt Riquarts, translated by Gillian Horton-Krüger. Routledge. https://doi.org/10.4324/9780203357781.

Micro:bit educational foundation. n.d. “Meet Micro:Bit.” Accessed December 9, 2019a. https://microbit.org/guide/.

———. n.d. *The Micro:Bit*. Image. Accessed December 16, 2019b. https://www.microbit.org/guide/.
NEUC. 2019. "Delevaluering af DR ultra:bit." Naturfagenes evaluerings- og udviklingscenter (NEUC). https://www.dr.dk/skole/ultrabit/undersoegelse-ultrabit-har-stor-virkning.
Neyland, Daniel. 2008. *Organizational Ethnography*. Los Angeles: Sage.
Pitkänen, Kati, and Hanne Voldborg Andersen. 2018. "Empowering Teachers and New Generations through Design Thinking and Digital Fabrication Learning Activities." In *Proceedings of the Conference on Creativity and Making in Education*, 55–63. FabLearn Europe'18. Trondheim, Norway: Association for Computing Machinery. https://doi.org/10.1145/3213818.3213826.
Pitkänen, Kati, Megumi Iwata, and Jari Laru. 2019. "Supporting Fab Lab Facilitators to Develop Pedagogical Practices to Improve Learning in Digital Fabrication Activities." In *Proceedings of the FabLearn Europe 2019 Conference*, 1–9. FabLearn Europe '19. Oulu, Finland: Association for Computing Machinery. https://doi.org/10.1145/3335055.3335061.
Saldaña, Johnny. 2013. *The Coding Manual for Qualitative Researchers*. 2nd ed. Los Angeles: SAGE.
Sharp, Helen. 2019. *Interaction Design 5e*. Indianapolis, IN: John Wiley and Sons.
Smith, Rachel Charlotte, Ole Sejer Iversen, and Mikkel Hjorth. 2015. "Design Thinking for Digital Fabrication in Education." *International Journal of Child-Computer Interaction*, Digital Fabrication in Education, 5 (September): 20–28. https://doi.org/10.1016/j.ijcci.2015.10.002.
Spradley, James P. 1979. *The Ethnographic Interview*. New York: Holt, Rinehart and Winston.
———. 1980. *Participant Observation*. New York: Holt, Rinehart and Winston.
Troiano, Giovanni Maria, Sam Snodgrass, Erinç Argımak, Gregorio Robles, Gillian Smith, Michael Cassidy, Eli Tucker-Raymond, Gillian Puttick, and Casper Harteveld. 2019. "Is My Game OK Dr. Scratch? Exploring Programming and Computational Thinking Development via Metrics in Student-Designed Serious Games for STEM." In *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, 208–219. IDC '19. Boise, ID, USA: Association for Computing Machinery. https://doi.org/10.1145/3311927.3323152.
Tuhkala, Ari, Marie-Louise Wagner, Nick Nielsen, Ole Sejer Iversen, and Tommi Kärkkäinen. 2018. "Technology Comprehension: Scaling Making into a National Discipline." In *Proceedings of the Conference on Creativity and Making in Education*, 72–80. FabLearn Europe'18. Trondheim, Norway: Association for Computing Machinery. https://doi.org/10.1145/3213818.3213828.

Tyrén, Markus, Niklas Carlborg, Carl Heath, and Eva Eriksson. 2018. “Considerations and Technical Pitfalls for Teaching Computational Thinking with BBC Micro:Bit.” In *Proceedings of the Conference on Creativity and Making in Education*, 81–86. FabLearn Europe’18. Trondheim, Norway: Association for Computing Machinery. https://doi.org/10.1145/3213818.3213829.

Ventä-Olkkonen, Leena, Heidi Hartikainen, Behnaz Norouzi, Netta Iivari, and Marianne Kinnula. 2019. “A Literature Review of the Practice of Educating Children About Technology Making.” In *Human-Computer Interaction – INTERACT 2019*, edited by David Lamas, Fernando Loizides, Lennart Nacke, Helen Petrie, Marco Winckler, and Panayiotis Zaphiris, 418–41. Lecture Notes in Computer Science. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-29381-9_27.

Wing, Jeannette. 2006. “Computational Thinking.” *Communications of the ACM* 49 (3): 33–35.

———. 2011. “Reseach Notebook: Computational Thinking -- What and Why?” *The Link*, 2011. people.cs.vt.edu/~kafura/CS6604/Papers/CT-What-And-Why.pdf.