Høgskolen i Østfold

Digital Fabrication in Norwegian Arts Education

Master's Thesis in Applied Computer Science – Interaction design
Faculty of Computer Science

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Abstract

As we progress in the world of technology, we see that there is a need for future workers to obtain digital skills, as it has an influence on the economic growth within society. Furthermore, the rise of digital fabrication has shown the importance of innovation and problem solving skills. In the subject of arts and crafts, policy makers enforced teachers to apply digital fabrication in their practice. Compared to other fields, arts education has been resistant to incorporating digital fabrication. In this thesis, I explore the underlying issues pertaining to the barriers in applying technology in arts education and how teachers can be facilitated when introducing fabrication tools in their teachings. I adopted the methodology of Research through Design, rooting my project work based on an extensive literature review on the problem scope. A user-centered approach was applied with teachers in the form of interviews and task assessments. The thesis discovers that the lack of technical support, language barriers, and limited resources limit the use of digital tools to information retrieval. In addition, the thesis reviews existing fabrication technologies used for educational purposes. This led to the development of a web-based resource platform dedicated for Norwegian arts education, evaluated by four arts and crafts teachers. Through the evaluation of the prototype, findings suggest that art educators appealed to the reintroduction of current practices incorporated with technology. Furthermore, animated instructions aided the participants to perform the technical assembly. Finally, the results provide suggestions on how to expand the platform with additional topics and applications covering other areas within arts education using community engagement.

Keywords: *Digital Fabrication, Art Education, Digital Skills, Norwegian Education.*

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Chapter 1

Introduction

1.1 Background and Motivation

As a child born in the 90s, I have been lucky to experience the acceleration of technology. In the classroom, however, I had not personally experienced technology outside of extra curricular activities. In the later years, I gained an interest in tinkering with old electronic parts. The excitement of just simply connecting my phone to a speaker using jumper wires and probing into old electronics led to my background in computer engineering. Fast forward to today, children grow up with a vast variety of digital technologies such as smartphones, computers, and tablets. I assume that the generations to come will most likely be introduced to advanced technologies at a faster rate than previous generations. In my first year of the master's program, I had been enrolled in the course *"Interaction Design"*, where I learned the importance of designing to improve human lives. The field of Human Computer Interaction framed my way of thinking, which directed my inspiration towards the topic of this thesis.

My main motivation for this project derives from my experiences as a facilitator for our institution's Makerspace [1] for children. I have worked with primary and secondary children at our MakerSpace in Halden, focusing on programming and digital fabrication. During the summer camps, children created various prototypes of small robotic cars, 3D prints, and music machines. The older candidates were provided with advanced microcontrollers to expand on useful applications. Based on these experiences, I recognized that digital fabrication had the potential to inspire children with ideas that could be visualized with low-fidelity prototypes. Schools from around the county visited the university college to learn about 3D printing and block programming. As one who has had the opportunity to tinker with scraps and electronics, it was fun working with children in informal arenas that were also curious about technology, demonstrating engagement in creative projects with fabrication platforms and programming. Having access to technology gave children possibilities to obtain knowledge that they could use to their advantage in the years to come. These experiences inspired me to use this project as a platform to demonstrate the potential of digital fabrication for the next generation, especially in education.

Looking at the effects of the acceleration of digitization, we see that communities in well-developed countries attempt to optimize production and services. These efforts increase the need to equip the next generation of citizens with valuable skillsl (Peaslee, 1969). This takes us to the education sector, which has a significant role in shaping future workers. Countries that have a high proportion of the population in primary schools are more likely to achieve economic growth (Peaslee, 1969). I therefore recognize the value of exploring how future workers are being prepared for the unknown needs of society using digital tools (Kinnula et al., 2012).

[1] Makerspace Summercamp 2020 https://mlundsveen.github.io/sommer2020/

1.2 Purpose

The purpose of this study is to investigate how digital tools are currently being used in an essential subject that relies on practical work, namely, the subject of *"Arts and Crafts"*[2]. The aim of this master thesis is to design a solution that focuses on innovative craftsmanship in education with the aid of digital fabrication. The resulting work would explore children's creativity with the aid of digital fabrication and programming. In addition, the project needs to address the barrier of digital literacy among teachers and support their implementation of digital fabrication.

In 2006, the Norwegian government introduced digital skills as one of the essential skills to learn in K-12 schools as shown in Figure 1.1. This has led to changes to the national wide curriculum in K-12 programs. Policy makers have created a precedent emphasizing on the importance of developing digital skills for teachers and students alike in all subjects(Traavik et al., 2009).

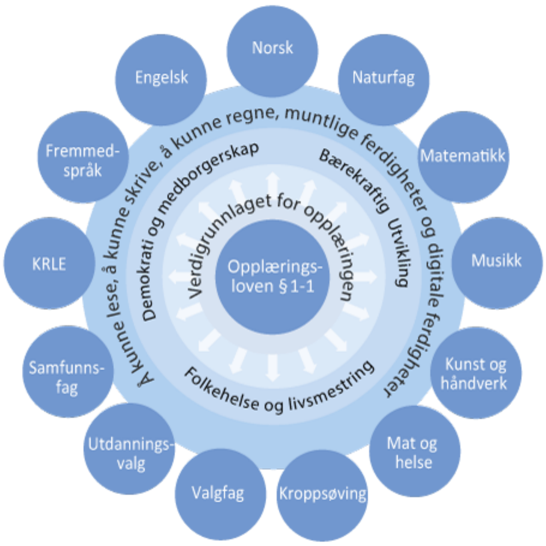

Figure 1.1: The Norwegian Government's overview of values and fundamental skills.

[2]Norwegian translation: Kunst og Håndverk

In the case of arts and crafts, previous reports highlight the low use of digital tools, as teachers focus on tasks that involve information retrieval and video editing (Vavik et al., 2010; Espeland et al., 2013). Despite initiatives towards digitization in the education sector, reports suggest that there are wide discrepancies between teachers in applying digital skills in art education (Sømoe, 2013). This project will therefore investigate the factors that influence digital competence in arts and crafts. Furthermore, the work in this project will target K-12 programs.

1.2.1 Research Question

Based on the premises identified in the previous section, this project will take a qualitative approach with the following research question:

RQ 1: How can digital fabrication be introduced in the subject of arts and crafts ?

To answer this research question, we must first investigate the needs of the stakeholders within the problem scope, which is therefore I add two subresearch questions:

- **RQ 1.1:** What are the demands in the new curriculum and how do they affect the current use of digital tools in the subject of *"Arts and Crafts"* ?

- **RQ 1.2:** How can the introduction of digital fabrication be facilitated in the subject of *"Arts and Crafts"*?

The deliverable in this project will be a solution, based on data collection and related work that will support the teacher's needs when transitioning to the new curriculum that has been partially implemented in the time this thesis is being conducted.

1.3 Research Area

The nature of the research in this thesis investigates physical computing in formal educational settings. This project looks at the relationship between two elements. Firstly, we have digital fabrication, mainly in the focus area of *"making"* and maker culture, which is described in Section 2.3.2. The second element pertains to art education in Norway and how policy makers dictate the use of technology as well as its function in practice, explained in Sections 2.1 and 2.3.3. In addition, this study is within the academic field of Fablearn [3], which specializes in integrating principles within constructionist learning using technology in formal educational settings.

1.4 Report Outline

This thesis has been structured into the following chapters:

Chapter 1 is the current chapter, where I introduce the background and personal motivation for this project. I explain the problem scope, which revolves around the subject of arts and crafts, and the incorporation of digital fabrication. After defining the purpose of this project, the research questions are outlined.

Chapter 2 provides an extensive review on digital fabrication and education, creating a theoretical backbone for the project. The chapter will also shed light on the infrastructure of the Norwegian education sector and art education, which places my work in the context of the research questions stated in the first chapter. The theory presented will aid to establish requirements and provide inspiration to potential design concepts. In addition, some concepts will be defined, which operate as valuable information towards the suggested solution.

[3] About Fablearn https://fablearn.org/about/

Chapter 3 pertains to the research methods I used throughout the course of the study. I present Research through Design as my core methodology with a specific approach framed to suit the context of the project. This is followed by the adoption of a framework to apply RtD in practice. Furthermore, I present an overview of design activities in the context of prototyping using a research model. Finally, I outline how the field research will be performed, followed by an assessment of ethical considerations..

Chapter 4 gives insight into the entire process of designing and creating a prototype, from defining a design concept to the final product. Rooted in the framework presented in Chapter 3, I first look at findings from previous literature and current contextual knowledge from preliminary data collection. This leads to a brief assessment towards the definition of the prototyping goal. Further documentation of the design process will then direct the reader to a suggested prototype concept. The chapter concludes with a detailed documentation of how the prototype is designed and created.

Chapter 5 presents the prototype in its final form, based on the design activities from Chapter 4. The chapter will describe the features of the prototype briefly with reference to the design choices made prior to implementation.

Chapter 6 pertains to the findings from the evaluation of the prototype. These findings have been grouped into categories based on the features of the prototype. This is followed by how the prototype can function in arts education based on responses from participants.

Chapter 7 provides a discussion of the findings from the previous chapter in relation to the research question. The discussion will also be framed on the basis of the theoretical background and conceptual knowledge obtained from data collection techniques. In addition, I reflect on my experiences with the core methodology and design choices. Furthermore, I present reflections on how the ongoing pandemic has had an influence on conducting research in this study.

Chapter 8 presents the conclusion to the study, followed by an assessment of potential limitations during the course of this study. The thesis ends with suggested directions for future work.

Chapter 2

Related Work

This chapter provides insight into the domains of art education and the incorporation of digital tools. As the thesis concerns the Norwegian education system, the chapter begins by presenting its infrastructure. Furthermore, I frame the context of this thesis by presenting the origins of the subject of Arts and Crafts, outlining the relevant aspects of its curriculum in relation to digital fabrication. Subsequent sections will focus on the origins of digital fabrication and its relevance to education in the form of a literature review.

2.1 Norwegian education system

This section presents the infrastructure of the education system that is relevant for the research area in this thesis. I will also provide insight into important elements within the system that is in use by Norwegian teachers in today's schools.

The education system in Norway applies to multiple levels of education from elementary to lower secondary, to upper secondary school for children from 6–16 years old. Primary education in Norway is referred to as *"Grunnskole"*. Table 2.1 summarizes the division of students in the Norwegian school system based on age. Primary and lower secondary schools pertain to one common curriculum and is mandatory for children in Norway (Imsen, 2020). According to the national database for statistics in Norway, there were 635,497 students in primary/lower secondary education in 2020, 443,967 of whom were registered in primary school (1^{st} to 7^{th} grade)[1]. This indicates that a significant part of the population could have a significant impact on the economic development of their society in the coming years (Peaslee, 1969).

Level of education	**Age range**	**Norwegian translation**
Elementary School	6 - 13	*Barneskole*
Lower Secondary School	13 - 16	*Ungdomsskole*
Upper Secondary School	16 - 19	*Videregående skole*

Table 2.1: Summary of how the Norwegian school system is divided.

The Norwegian Ministry for Education and Research (*Kunnskapsdepartementet*) have established premises for learning through *"The Education Act"* (Opplæringsloven, 1998), among other regulations to ensure that all institutions provide students with consistent learning outcomes for all schools in the nation. This act reinforces the notion that the educational system must ensure that students will be able to expand on their expertise, democratize expression through their work and be prepared for the future (Opplæringsloven, 1998).

As mentioned earlier, the population has a significant number of students, a fact which gives policy makers, and most importantly, teachers, a great responsibility, as they have to ensure that their society can tackle unknown challenges in the future. The Ministry of Education under the *"Education act"* regulates a national curriculum (*"lærerplan"*) that schools must adhere to in their practice. This first formation of the national curriculum dates back to the early 1920s (Imsen, 2020). To shortly summarize the Norwegian curriculum consists of the following:

[1]National Database Statistics in Norway - Norwegian Primary Education: `https://www.ssb.no/utdanning/statistikker/utgrs/aar`

- Basic principles reflecting Norwegian values and interests.
- The type of subjects and respective number of hours to complete them.
- Specific curriculum for each subject with their subsequent core elements. Each subject is supplemented with learning outcomes. The project will target this area pertaining the subject of Arts and Crafts.
- General learning goals for the society.

As explained by Imsen (2020), the Norwegian curriculum is a legal document from policy makers that all teachers must apply to their teaching, in an attempt to shape students for upcoming challenges facing our society (Lyngsnes and Rismark, 2015). On the other hand, Imsen (2020) explains that the learning outcomes in a given curriculum can be interpreted by the teacher that is practicing it as shown in Figure 2.1.

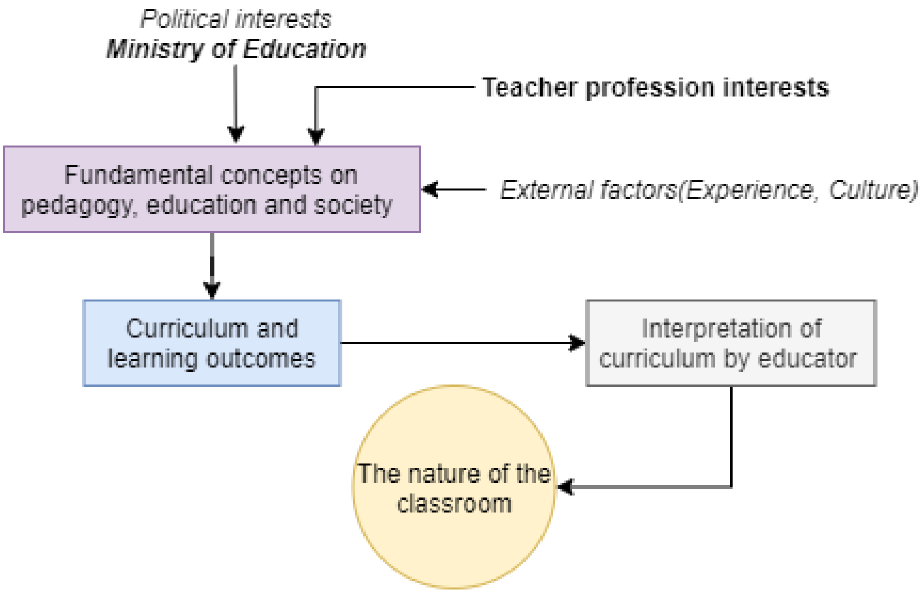

Figure 2.1: An illustration of how the curriculum is practiced in the classroom, influenced by political interests and the interpretation of the teacher (Imsen, 2020).

Each subject in the Norwegian curriculum has core elements, which are defined as the origins of the learning outcomes that the subject's teachers must adhere to. Unlike learning outcomes, core elements are crucial demands that consist of definitions and ways of thinking (Kunnskapsdepartementet, 2020). Learning outcomes can provide teachers with some form of autonomy in their practice, as long as they comply to the core elements of the subject. The author further explains that teaching is not predictable due to factors such as the learning abilities of the children, competency of the teacher, and most importantly, the nature of understanding of the classroom from school to school (Imsen, 2020).

2.2 Arts Education in Norway

This section focuses on "Arts and Crafts" in relation to fabrication and craftsmanship in Norwegian primary and lower secondary education, and the implications of integrating digital literacy, competence and skills for teachers and students.

Historically, Arts and Crafts in Norway was classified into three different separate subjects in the late 1800s: woodwork, handcrafts, and drawing (Sømoe, 2013). The subject was set to be reformed in 1960, when policymakers enforced a new system where the three subjects were forged into one. In the later years, prior to the reform of *"The Knowledge Promotion"*, the subject was conceptualized with three interdisciplinary areas (Sømoe, 2013). The three areas presented are as follows: (1) The knowledge of materials and crafting tools along with specified techniques, (2) artistic pedagogy and perspective analogy, and (3) critical perspective of visual culture (Sømoe, 2013).

2.2.1 Curriculum Changes in Norwegian Arts and Crafts

As the thesis will frame towards the research questions, we investigate the subject of Arts and Crafts, looking at fundamental concepts that are relevant in today's education. In this part of the chapter, I attempt to frame the relevant aspects of the curriculum in the context of digital fabrication.

In recent times, the Ministry of Education set new regulations consisting of core elements and learning outcomes that teachers must apply to their practice. As of the academic year of 2020-2021, the subject of Arts and Crafts is considered essential to obtain skills through practical hands-on work, creativity, and reflection over visual and tangible culture (Kunnskapsdepartementet, 2019a). Policy makers emphasize that the curriculum changes will prepare students for a society that requires innovation and practical intuition. Furthermore, students will master the ability to operate on artifacts within current ethical considerations. In addition, they require teachers to encourage curiosity, and playful creation when constructing products. The changes in arts education also emphasized the importance sustainability in coordination with digital expression (Kunnskapsdepartementet, 2020).

2.2.2 Core Elements in Arts Education

As mentioned in Chapter 1, the Norwegian government set a precedent for implementing computing in all subjects with their education reform referred to as *"Knowledge Promotion"* in 2006. Digital skills were one of the five essential competencies that were to be implemented in all subjects in the curriculum (Kunnskapsdepartementet, 2019b). In 2019, policy makers in Norway reinforced their intentions by applying explicit changes in all subjects. When it came to Arts and Crafts, the changes are characterized by the reintroduction of the core elements. These elements influence the specifications of the learning outcomes and must be applied throughout primary and lower secondary education[2].

- **Handcrafting**: Students will learn how to work with raw materials and digital tools in an ethical and sustainable way. The learning outcomes connected to this core element pertain to combing traditional crafting techniques with digital fabrication.

[2] Core Elements in arts education in Norway: `https://www.udir.no/lk20/khv01-02/om-faget/kjerneelementer`

- **Art and Design Process**: Students will learn how to engage in exploring creativity with development and innovation as primary goals. The learning outcomes connected to this core element challenge students to learn programming skills to create interactive products. They also emphasize the importance of exploring new technology.
- **Visual Communication**: Students will learn how to create interactive experiences by experimenting with the second and third dimensions in addition to explicit digital expression. Here, the learning outcomes associated with this core element will challenge students to reflect on the development process when creating products.

These core elements outlined by the Ministry of Education are relevant for this research, as they combine tangible construction with the implicit use of digital tools (Kunnskapsdepartementet, 2019a).

2.2.3 Learning Outcomes in Arts Education

The curriculum is supplemented with a list of learning outcomes[3] for each class in primary and lower secondary students. The goals set from the 5^{th} to 10^{th} grade require explicit digital fabrication technology in the context of Arts and Crafts and will therefore be the target group for this thesis.

I will now present the learning outcomes for Norwegian arts education, which rooted from the core elements presented earlier:

- For students between the 5^{th} and 7^{th} grade:
  - Use digital tools to plan and present processes and products. (**Core element: Art and Design Processes.**)

[3]Learning outcomes for Arts and Crafts from the Directory of Education: `https://www.udir.no/lk20/khv01-02/kompetansemaal-og-vurdering/kv159`

  - Implement programming to create interactive and visual expressions. (**Core element: Visual Communication.**)
  - Learn how to use electrical crafting devices to work with the mentioned materials in a safe and sustainable matter. (**Core element: Handcrafting.**)

- For students between the 7^{th} and 10^{th} grade:
  - Explore the use of technology with materials when constructing products. (**Core element: Handcrafting**)
  - Explore how new technologies can provide possibilities to experience creative processes when creating products. (**Core element: Art and Design Processes**)
  - Learn how to visualize interactive illustrations with the use of hand drawing, 3D modeling, and other digital tools. (**Core element: Visual Communication.**)

Connecting the learning outcomes to the core elements of the subject provides clarity on which parts of the curriculum relate to digital fabrication. Furthermore, by framing a pedagogic perspective, I can use these points to improve communication and most importantly, a better understanding of teachers as users of digital tools.

2.3 Literature review

In this part of the chapter, the literature review will first describe the origins of digital fabrication, followed by how fabrication technology has had an influence on society and education. In addition, I present perspectives from previous literature pertaining to computing in Norwegian education. Finally, I outline how previous literature has perceived and addressed the implementation of digital fabrication in the subject of Arts and Crafts. The literature review functions as a preliminary activity for applying RtD as explained in Section 3.1.1.

2.3.1 Digital Fabrication (History and origins)

Digital Fabrication is defined by Iivari et al. (2016) as the *"making of physical digitally enhanced artifacts as well as the making of materialized objects by means of digital models."* It involves a conversion of a digital visualization into a physical, tangible entity through a computer using a dedicated fabrication program (Bull et al., 2010). In this context, digital fabrication is the process of using technology as a tool to create tangible products, as shown in Figure 2.2.

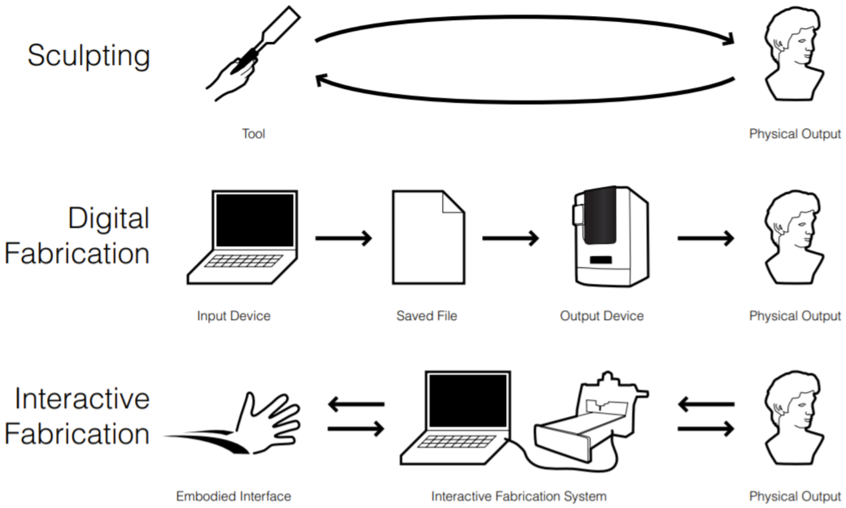

Figure 2.2: A comparison between traditional crafting and digital fabrication by Willis et al. (2010).

In 1952, researchers at the Massachusetts Institute of Technology created the first machine-controlled tool to fabricate industrial components for small airplanes. By using a numerical machine, they were able to produce complicated pieces that were beyond the craftsmanship of the hands of mechanics, using metallic drills that could cut through hard materials (Pease, 1952). This can be considered the first wave of digital fabrication in practice. Computer controlled manufacturing has existed for decades, however, according to Gershenfeld (2012), it was limited to large-scale machines dedicated to cutting material. In the 1980s, the revolution of digital fabrication progressed with the introduction of additive manufacturing. Looking back at the first machine-controlled fabrication tool, one could see that is was not possible to freely manipulate the internal structure of the materials (Guo and Leu, 2013). In the later years, the emergence of additive manufacturing, or 3D printing made it possible to construct objects using three-dimensional model data (Guo and Leu, 2013).

The advances within information technology have allowed digital tools to be accessible to the public, providing multiple possibilities to obtain newer skills (McMullen et al., 2003). Neil Gershenfeld described a vision where *"people will be able make almost anything using a personal fabricator"* (Gershenfeld, 2012). Similar to the use of computers a few decades ago, it was difficult for the average consumer to be able to use digital fabrication tools, as they were suited for technical hobbyists and engineers (Mota, 2011; Blikstein, 2013). Moving forward in time, the use of fabrication tools such as 3D printers were re-introduced in the form of kits accompanied with a simplified, yet comprehensive set of instructions. This trend empowered the use of digital tools to the ordinary consumer, trending towards universally operative technology that was accessible to all, regardless of experience (Mota, 2011; Diez, 2012). Gershenfeld (2012) explains the potential of digital fabrication with the following quote: *"Digital fabrication will allow individuals to design and produce tangible objects on demand, wherever and whenever they need them. Widespread access to these technologies will challenge traditional models of business, aid, and education."*.

Digital fabrication progressed further with the establishment of *"Fablabs"*, coined by Gershenfeld (2012). According to Krannich et al. (2012), Fablabs, or Fabrication labs are dedicated facilities that contain 3D printing devices, laser cutters, milling machines, vinyl manipulators and other machines accompanied with electronics and programming platforms. Fablabs have expanded to the general public at a global scale with over 100 listed labs (Posch and Fitzpatrick, 2012). Around the world, researchers have referred to community based digital fabrication facilities as *"Innovation labatories", "Media labs", "Hacklabs", "Makerspaces"* and *"Hackerspaces"*. Some of these spaces and workshops are run voluntarily while others are supported by central institutions such as schools, universities, museums and libraries (Smith et al., 2013). The general public are now able to transform data into physical entities at a lower cost for research groups, enterprises, and educational institutions (Smith et al., 2013). Consumers have gained access to rapid prototyping technology from Universal[4] and 3D systems[5]. In recent times, consumers have been able to acquire next generation fabrication tools from companies such as Ultimaker[6], Prusa[7], Makerbot[8], and Cricut Explorer[9]. In addition, these tools allow users to not only create components for personal projects, but also create parts that can modify, upgrade, or replace specific parts of their personal fabrication machines (Blikstein, 2013).

Diez (2012) also highlights the sharing culture of digital fabrication: *"Today, knowledge is not owned by single individuals, nor is it concentrated in major centers filled with gurus and post-PhD people, it relies on collaboration and networks and is evolving and spreading every second."* The reflections on knowledge sharing using the internet as the medium by Diez (2012) correlates with the already embodied vision of personal fabrication by Gershenfeld (2012). Entrepreneurs and start-up businesses began to expand in 2007 with the introduction of online fabrication services and distributed manufacturing networks (Mota, 2011). Online fabrication services were appealing to independent designers that were interested in small scale production of their products. Furthermore, it was a useful institution for average consumers looking for a custom product. Distributed Manufacturing networks were also created as a platform for designers with fabrication tools in the context of knowledge and resource sharing (Mota, 2011).

As we turn towards today's society, previous literature indicates a transition to bring digital fabrication away from workshops to the personal home. The shift towards

[4]Universal: https://www.universal-systems.com/
[5]3D systems: https://www.3dsystems.com
[6]Ultimaker: `https://ultimaker.com/`
[7]Prusa 3D Research: `https://www.prusa3d.com/about-us/`
[8]Makerbot: `https://www.makerbot.com/`
[9]Circuit Vinyl Cutters: `https://cricut.com/en_us`

personal fabrication is similar to how personal computers were perceived in the 1970s (Gershenfeld, 2012). The increased availability of software for design and manufacturing combined with the constant decrease of machines, in addition to the general public's use of today's online platforms shifts personal fabrication away from experts and hobbyists (Lipson and Kurman, 2010). The next generation of digital fabrication tools focus on inventions outside of fixed spaces. Peek (2019) introduces *"Popfab"*, a multipurpose, portable digital fabrication tool that can provide a user with milling, 3D printing along with multiple operative fabrication modules such as cutting and pi-petting. Dougherty (2012) introduces the *"maker"* movement, supporting the prediction from Gershenfeld (2012) that anyone should be able to construct anything with the access to digital tools. Dougherty (2012) outlines that the democratization of *"Making"* will have an influence on businesses, government, and education.

2.3.2 Education and Digital Fabrication

In this section, literature concerning the implications of the developments in digital fabrication in education will be presented.

While the 20^{th} century has been characterized by democratization through the use of a personal computer Bull et al. (2010) suggests that the 21^{st} century would be characterized by the democratization of tangible construction through personal fabrication(Iwata et al., 2020). There are parallels between computing and fabrication that can be anticipated according to researchers, which is that digital fabrication has the potential to enhance learning (Mellis et al., 2013; Eisenberg, 2007). In addition, we also see the benefits of implementing technology in education, as computing skills have been called to be incorporated in STEM and art education (Montero, 2018; Song, 2020). In the context of education, the term *"Making"* has been described as: *"a class of activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented toward making a "product" of some sort that can be used, interacted with,* *or demonstrated"* (Martin, 2015). The author explains further that making in education can be characterized as the combination of traditional crafts with digital fabrication tools such as laser cutters, 3D printers, microcontrollers and Computer Numerical Control (CNC) machines.

Considering these recent advancements of personal computing in the 20^{th} century (Bull et al., 2010), educational leaders were challenged to reflect on how the upcoming digital fabrication revolution could be applicable to education at the 11^{th} National Technology Leadership Summit. Previous literature suggests that digital fabrication will be used as a platform to uplift the educational system (Bull et al., 2010; Stickel et al., 2017). Fabrication through computing has been encouraged by Eisenberg (2002) when it came to mathematical crafts, advocating that by creating abstract materials using paper strings and 3D models, students will be able to enhance their understanding of the fundamental principles of the subject. This was supported by Berry et al. (2010) in their study of engineering principles in elementary mathematics education using digital fabrication. In 2005, fabrication communities were introduced to students through programs such as *"Learn2Teach"* from MIT, leading to a trend and the launch of dedicated FabLabs for K-12 schools in addition to the introduction of toolkits that had a pedagogic approach for beginners (Blikstein and Krannich, 2013).

Eisenberg (2007) also made the case of the relevance of fabrication technologies in education: *"Fabricated objects can change educational settings, enabling those settings to evolve with children's (or, in some cases, teachers') interests and skills."* In addition, the author presents a vision where children can use their computers as a portable "shop" to develop artifacts within their design. This is supported by the theoretical ground established by Montero (2019) showing that children who demonstrate hands-on learning with digital tools with no prior experience or knowledge achieved positive learning outcomes while simultaneously being engaged. This was also noted in the emergence of the maker movement from Dougherty (2012): *"When you're making something, the object you create is a demonstration of what you've learned to do, thus you are providing* *evidence of your learning."* Furthermore, it has been established that digital fabrication in K-12 related activities in schools provide children with the ability to not only adapt to the acceleration of technology, but also the opportunity to learn *"fundamental societal issues such as digital citizenship and complex problem solving."* (Eriksson et al., 2019; Hjorth et al., 2016).

The next generation of learners in K-12 will be growing up with digital tools, a familiarity that teachers and technical facilitators can use to construct innovative products (Schön et al., 2014). Digital fabrication for children stimulates the notion of *"learning by doing"*, rooted in the theory of constructionism by Papert (1986). Students can develop an open mind while stimulating engagement as they produce tangibles while also achieving concrete results (Schön et al., 2014). Eisenberg (2007) outlined three themes within fabrication in education: Construction as ornamentation, personal expression, and intellectual approach, which can be connected with the core fundamentals of arts education in Norway in Section 2.2.2.

Schön et al. (2014) explained that it is important for educators to be updated on current advancements, resources, and its implications on education. The roots of digital fabrication in education stem partially from the first half of the 20^{th} century where progressive teachers expressed that children could explore development in all senses of learning through construction. According to Papert (1986), learners would use tools to construct things, which results in generating knowledge. Such activities can stimulate engagement in how they handle raw materials and consider the potential applications that can be useful to develop on (Van der Veen et al., 2019). Montero (2018) suggests that must be a formal pedagogical approach in place prior to the introduction of digital fabrication in the classroom. In addition, Eisenberg (2007) suggested that fabrication communities should have a goal to provide students with inexpensive equipment along with smaller-scaled, portable fabrication tools. Furthermore, Blikstein's calls for educational approaches that foster innovation with the following statement: *"students' projects should be deeply connected with meaningful problems, either at a personal or community* *level, and designing solutions to those problems would become both educational and empowering"* (Blikstein, 2013). Furthermore, Blikstein promotes Papert (1986) theory of constructionism (Bull, 2005), adding that the theory is at the very core of what the implications of digital fabrication mean for education, not by replacing traditional learning, but rather by empowering children using technology as an *"emancipatory tool"* (Blikstein, 2013).

On an international level, previous literature outlines how countries show interest in a growing economy stimulated by knowledge and innovation. However, in some cases there can be uncertainty. For instance, the BBC program in England produced low-cost computer boards such as Micro:bit as shown in Figure 2.3. The boards were supplemented with programming platforms (Blikstein, 2018). As a result of such initiative, progressive education made room for new content that defied the imaginations of experienced hobbyists, engineers (Eversmann, 2017), architects (Celani, 2012) and computer scientists while simultaneously opening doors to sustainability and creator space for children, no matter the background (Blikstein, 2018).

Figure 2.3: The first iteration of Micro:bit when introducing in the BBC program in the United Kingdom.

Despite the call for implementing digital fabrication in schools and increasing production of low-cost fabrication tools, there are still a significant number of schools that can not acquire them. Blikstein and Krannich (2013) argued that it is difficult for institutions to balance between building spaces, training teachers, and managing facilities, a notion supported by Schad and Jones (2020). According to Iwata et al. (2019), this has been addressed by utilizing mobile Makerspaces to save costs on building facilities. Blikstein and Krannich (2013) suggested that institutions should create incentives that reward teachers that facilitate the use of technology in the classroom. A lack of knowledge and initiative can lead to poor learning outcomes in the context of digital fabrication (Montero, 2018). Based on the theoretical background presented on digital fabrication, I have reason to believe that the educational sector has the potential to use digital tools in K-12 programs, however, it must be seamlessly integrated in practice by creating meaningful tasks that provide not only an incentive to facilitate, but also invite children to produce useful knowledge generated by the product they are constructing Papert (1986).

2.3.3 Computing in Norwegian education

According to the OCED (Organization for Economic Cooperation and Development), Norway was one of the leading countries on the level of accessibility of technology in schools (OECD, 2015). Furthermore, a report by Sjøtun (2013) shows that 75% of students in Norwegian education register a daily use of their computer. The same report also highlights a rapid increase of younger students obtaining computers between 2009 and 2012. However, according to Lyngsnes and Rismark (2017), having access to technology in the classroom does not necessarily correlate to productive learning when used carelessly (Lyngsnes and Rismark, 2017).

One challenge that education leaders and teachers in Norway face is that they adapt their work towards digitization without a progressive transition Ottestad et al.

(2014a). Ottestad et al. (2014b) raised concerns of how policy makers introduced digital skills to teachers, questioning how one can compromise inconsistent levels of digital competence to comply with the new curriculum. In the early stages of *"The Knowledge Promotion"*, Krumsvik (2006) claimed that there were discrepancies between the call for ICT (Information and communication technology) from policy makers and the reality of how schools would be practicing it. Krumsvik (2006) adds that despite the challenges that teachers face with digital tools, one must recognize the value in the tools that empower information retrieval and sharing, which will have an impact in upheaving education for the unforeseeable future.

Based on the findings from this part of the literature review, I recognize that teachers have a need to be supported when introducing digital fabrication so they can comply with the new demands. This is supported by Lyngsnes and Rismark (2017), who adds that teachers must use technology as a tool and should incorporate it in specific tasks with a conclusive goal to achieve a learning outcome. Furthermore, Song (2020) expressed the need to explore the possible applications of implementing digital processes into traditional practices.

2.3.4 Incorporating Digital Tools in Arts Education

There seems to be few studies that address the implementation of digital fabrication in arts education. Despite the incorporation of digital tools in education, related work suggests that the use of technology in arts education has been minimal compared to other subjects. Song (2020) sheds light on the limited use of digital fabrication in visual arts subjects. Previous literature documents the use of digital tools in art education for information gathering using the internet (Ettinger, 1988). As Song (2020) described, it is not a new phenomenon that design education has been dismissive to the advancement of technology. Already in the 1980s, there was resistance towards technology from teachers practicing arts. Ettinger (1988) provided a perspective on this matter by investigating four pedagogical issues when looking at the relationship between arts education and the implementation of technology.

The first issue pertains to the disciplinary traditions, in which Ettinger (1988) explained that the rationalistic perception of using technology in STEM subjects was difficult to apply to art educators. This is due to the notion that art education is characterized as an interpretative field. Naturally, this perception conflicted with the use of technology at the earliest stages of implementation. According to previous studies, the resistance in adopting technology in arts education is due to teachers' and students' perception that digital tools hold low artistic value (Song, 2020; Ettinger, 1988).

The next pedagogic issue from Ettinger (1988) focused on the use of computers as a visual arts medium. Art educators argued that while computers focus on the process, the work of art products focuses on the value it holds. Computers as a visual arts medium are organized and document every step of the process, which can be replicated, which conflicts with the essence of arts education for traditionalists. Ettinger (1988) does however shed light on the measures taken to address this issue with the use of programs such as Microsoft Paint[10]. In the later years, the use of computers as a visual medium has been static, with limited use in the education sector to this day Song (2020).

The third issue raised by Ettinger (1988) is about the way computers have been designed. Most design programs have been created for and by design professionals. This creates a barrier for teachers as they have to spend more time learning to use the technology while simultaneously practicing their teachings. As mentioned in Section 2.3.3, there seems to be a gap between what is visioned and what is applicable in practice, and previous literature suggests that the way digital tools have been developed has had an influence in this issue.

[10]Microsoft Paint, used to create 2D illustrations: `https://support.microsoft.com/en-us/windows/get-microsoft-paint-a6b9578c-ed1c-5b09-0699-4ed8115f9aa9`

The fourth and final pedagogical issue focused on the formation of the curriculum and the role of the teacher. Ettinger (1988) described that digital competence was perceived to be part of an interdisciplinary nature. Despite that, the infrastructure of educational sectors supported traditional discipline-specific fields, making it difficult to incorporate it to arts education. This is in addition to the limited resources that teachers lack to introduce digital fabrication. Even in this day of age, where almost every school has some access to computers, Ettinger (1988) explains that traditional teachings are still being prioritized. According to Song (2020), the heavy load of learning new technologies,lack of technical support, and limited resources become significant barriers for teachers and must be addressed.

A national education report from 2009 presents an analysis of the use of digital tools in Norwegian schools in all subjects, including Arts and Crafts (Vavik et al., 2010). The study reported that teachers in Arts and Crafts incorporate low levels of technology in their practice with students in primary and lower secondary education. This resonates with findings from other authors pertaining to the use of technology in arts education (Sømoe, 2013; Song, 2020). However, it does not mean that the attitudes towards using technology among teachers were negative: *"The most likely cause of limited use of digital tools in arts education is that the subject is very broad...the time available is limited."* (Vavik et al., 2010). The authors also report that the enforcement of digital tools has led to unorganized tasks. This was demonstrated in cases where teachers with lower digital competence organized workshops where the students are provided with computers and work together to solve problems with no facilitation. Dougherty (2012) argued that teachers themselves must understand the rewards of making, as the tangibles constructed by students are representations of what they are learning.

Traavik et al. (2009) associates the use of digital tools in Arts and Crafts to multimedia production, leaving out physical construction. Sæthre-McGuirk (2017) provided a list of educational activities for teachers using primarily digital media tools (Windows Movie Maker, iMovie, Cameras) with a focus on visual skills using technology.

This project attempts to investigate how digital fabrication can be integrated into arts education. By revising previous work pertaining to this topic, we can address the research void that can be supplemented with the contributions from this project.

2.4 Summary

In this chapter, I have provided an overview of the Norwegian education system, followed by the origins of the subject of arts and crafts. Furthermore, I have presented important elements in arts education and explored learning outcomes pertaining to digital fabrication for students between the 5^{th} and 7^{th} grades. I have also shed light on the origins of digital fabrication and its applications in education with a literature review. In addition, I provided insight into the various challenges the education sector faces regarding digital tools in arts education. Based on this theoretical background, I see that there is a need to support art educators that are required to incorporate digital fabrication in the classroom.

Chapter 3

Methodology

In this chapter, I present the research approach that I have applied in the project work. Based on this core methodology, I outline the methods used to answer the research questions found in Section 1.2. A *Research through design* approach was used in this thesis as it allows me to use digital fabrication resources in the form of "artifacts" to explore possible applications in art education. As explained in Chapter 1, the use of digital tools in education has been encouraged by policy makers since 2006. Despite that, there have been discrepancies in implementing digital tools as intended.

The challenges in implementing technology in art education found in Chapter 2 create grounds to reevaluate the introduction of digital fabrication in arts and crafts. Furthermore, I am aware that the selection of this methodology could result in a solution that may diverge from what was originally planned. Therefore, I find it important to present the methods used in relation to the the core methodology. Furthermore, I have made an effort to employ methods relevant to the philosophy of Research through Design. To aid in my selection of design activities, I adopt a framework to apply Research through Design in my work. In addition, the description of these methods allows for critical reflection in later chapters.

3.1 Research Through Design

Research through Design (RtD) in its core is about making use of activities associated with a design process as a strategy to generate new knowledge as illustrated in Figure 3.1 (Frayling, 1994). I needed a research approach that allowed me to explore the teachers' perception of technology in relation to practical work using artifacts. Arts and crafts as explained in Section 2.2 involves the production of tangibles. I therefore argue that a design research approach is best suited to explore the needs of the teachers, while simultaneously contributing to a realistic solution.

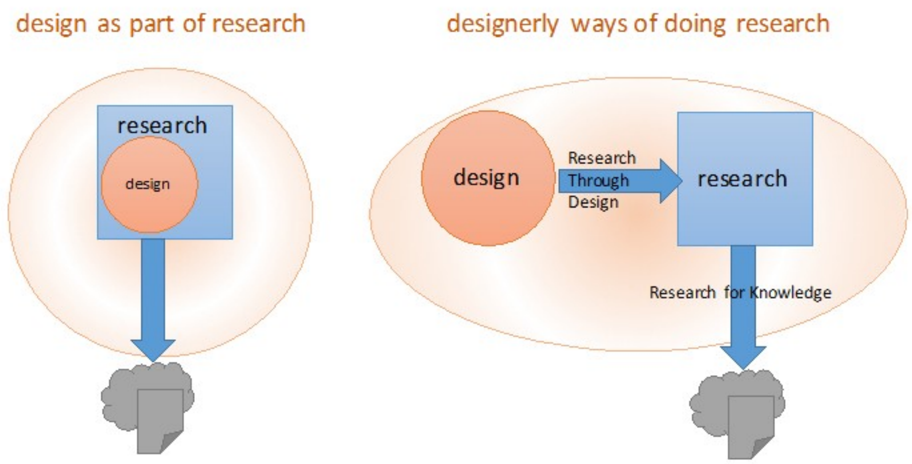

Figure 3.1: An illustration of research through design, taken from the Interaction Design Foundation

According to Zimmerman and Forlizzi (2014), RtD can be useful to investigate existing products in relation to a given problem. In addition, a paper by Koskinen et al. (2011) explained that the knowledge produced from RtD is not a prediction of what should be created, but rather a proposal of a solution. This implication is within the problem scope, as the project looks into how digital tools should be used in arts education. *Research through Design* was first presented by Frayling (1994) when discussing the term *research* in the context of art and design. Previous researchers had used *"research"* and *"design"* in different contexts. According to Stappers (2007), the debate on the relationship between research and design was characterized by their implicit definitions, in addition to abstract over-generalizations. On one hand, design can be interpreted as the action of creating a product while as research is the process of inquiring and generating knowledge (Zimmerman et al., 2007). In their explanation of RtD, Koskinen et al. (2011) argued that the word *"design"* is ambiguous and has numerous categories.

Stappers (2007) argues that both *design* and *research* improve the understanding of the user's needs. In addition, the terms are characterized by *"iterative cycles of generating ideas and confronting them with the world."* Frayling (1994) introduced a framework for research in arts and design, where he presented three areas within research through design based on previous work and personal experiences; *"materials research"*, *"action research"*, and *"development research"*. The author further explains that this approach is based on strengthening the understanding of users (Frayling, 1994).

Zimmerman et al. (2007) claims that design researchers engage in creating artifacts that function as crafted questions. Furthermore, these artifacts *"stimulate discourse around a topic by challenging the status quo and by placing the design researcher in the role of a critic."* (Zimmerman et al., 2007). Considering the nature of the research questions from Chapter 1, this is a similar notion in the sense that the topic of digital fabrication in art education must be examined in detail.

In an analysis of RtD as a research method, (Zimmerman et al., 2010) wrote about the lack of guidelines when applying it, as they explain the importance of documenting every stage of the process. In short, the design that is to be used for generating knowledge must have a clear intention in a given problem space. This is an important consideration that has been applied in my documentation of the design process. RtD contributes to the field of *Human Computer Interaction* by providing *"a shift to investigating the future as a way of understanding the world that should be brought into being"* (Olsen, 2014, p. 178).

Although Frayling (1994) introduced design as a way to obtain knowledge by design researchers, the practices have varied throughout the years (Zimmerman and Forlizzi, 2014, pp. 167-170). In an attempt to narrow the scope within RtD for this thesis, I will adopt the framework proposed by Koskinen et al. (2011), as it categorizes the practice of RtD into three catagories: *Lab, Field, and Showroom.* Each category is described with a set of conditions for the researcher to adhere to. The lab approach is concerned with studying a design in a controlled environment with the use of probes to gather data. The field approach focuses on contextualizing the inquiry in a realistic setting. The showroom approach leans towards an artistic view rather than the scientific one. This thesis falls within the field approach in the context of RtD, considering that arts education is practical, and requires a form of interaction between students, teachers, and the digital tools needed to fulfill the demands made by policy makers.

To develop a solution that can support the introduction of digital fabrication, we must first understand how digital skills are currently perceived in arts and crafts. Furthermore, any person who interacts with a design assesses it based on their personal perspective and understanding, which in turn shapes they way they use it (Koskinen et al., 2011). Teachers may have different attitudes to the use of technology based on their background and interpretation of the learning outcomes. This underlying theme to contextualize the use of technology is why I argue that the field approach is best suited for this project (Koskinen et al., 2011, p. 69).

3.1.1 Applying Research Through Design

Now that this thesis has established an overview of the methodological approach of research through design, I will now outline the structure of my work based on the proposed five step plan by Zimmerman and Forlizzi (2014) as shown in Figure 3.2. This follows the recommendation by Gaver (2012) who implied the importance of providing descriptions and documentation of the research process when applying RtD, as there are few restrictions on how to operate with the method.

The following is a description of the steps implemented in this thesis:

1. **Select**: In this step I select a problem or a design opportunity worth investigating. This is where the project's research questions come in as described in Chapter 1.

2. **Design**: In this step, I choose the RtD practice (Lab, Field or Showroom) that matches the context of the research topic. In this case, the field approach as explained in Section 3.1 will be the used. In the early stages of this step, Zimmerman and Forlizzi (2014) suggested to perform a literature review on the problem scope. The literature review for this thesis has been conducted in Chapter 2. After establishing an understanding over the problem scope, researchers start conducting design activities, outlined in Section 3.3. The work from these activities will result in a prototype.

3. **Evaluate**: In this step, a prototype is to be created and evaluated based on the work generated from the previous steps. Section 3.5.6 outlines the details of how the prototype will be evaluated.

4. **Reflect and disseminate**: After evaluating the prototype, I analyze the knowledge generated based on the practice selected. According to Zimmerman and Forlizzi (2014), work following a field approach will contribute into a discussion on the purpose set by the first step. This step can result in a long term solution to existing practices or a pathway to consider other perspectives.

5. **Repeat**: This is where the research returns to explore the work as this is an iterative process. Although Zimmerman and Forlizzi (2014) recommended to repeat this process, the time restriction on this thesis has limited the project work to go through steps 1 to 4. In Chapter 8, I present a set of suggestions for future work as guidance for the next iteration.

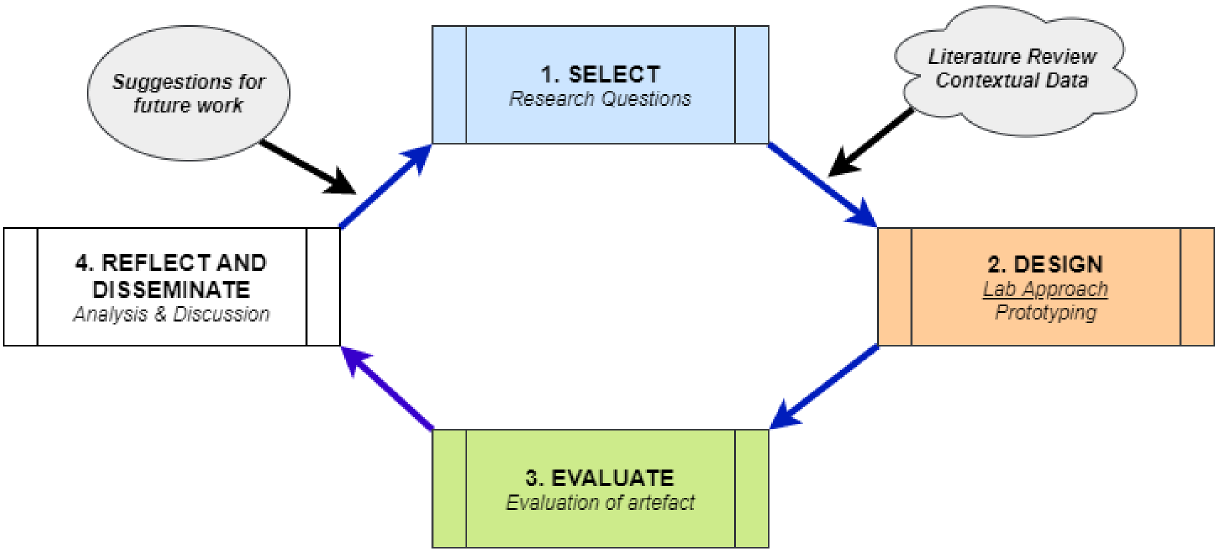

Figure 3.2: Illustration of the adopted RtD model for conducting the project work inspired by Zimmerman and Forlizzi (2014).

3.2 Literature Review

The literature review as explained in 3.1.1 operates as a prerequisite to gain understanding over the elements that pertain to this project: digital fabrication and its introduction in arts and crafts (Zimmerman and Forlizzi, 2014). Literature reviews are essentially a summary of theory and knowledge. It can be beneficial for providing a general overview of a relatively unexplored research area, informing on what has already been done and can place the research in a more clear and larger context (Knopf, 2006). To strengthen the validity of the collection of literature, it is important to prioritize accredited scientific journals and books.

I used *Google Scholar*, focusing on the top 25 hits on each search iteration. In addition, I observed the number of citations of the earliest papers to find key authors in order to snowball similar literature for in-depth exploration. After a thorough look at the initial search, I identified relevant journals using *"ACM Digital Library"*, and *"IEEE"* that covered my area of research. When it came to Norwegian education and Norwegian education in general, I have also used the institution's local library database, *"Oria"*[1] to find reliable literature.

The keywords used for the literature review were; *Digital Fabrication"*, *"Education"*, *"Making"*, *"K-12 technology"* ,*"Computing STEM"*, *"Arts Education"*, and *"Norwegian arts and crafts"* in combination with each other. Furthermore, I investigated the Norwegian education platform, exploring their curriculum to gain insight into how the educational system is formed in Norway, and what responsibilities apply to teachers and students. In total, I downloaded 97 papers, of which 68 of them were reviewed for this project. The findings from the literature review for this project can be found in Chapter 2.

3.3 Prototyping

This part of the methodology elaborates on how the second step in applying RtD (Zimmerman and Forlizzi, 2014) will be performed. The section begins by describing prototyping as a method for this project. Following that, I introduce the prototyping process as a central activity by adopting the research triangle by Fallman (2008), which covers three areas: *design practice*, *design studies*, and *design exploration.* The research triangle will be used to explain the relationship between each design activity in relation to the problem scope.

A prototype is described as a manifestation of a concept or design for potential users (Rogers et al., 2015, pp. 422-423). It takes many forms, from physical tangibles to software, to a paper-based design depending on the context of its use Houde and Hill (1997).

[1] Oria - the institution's database for literature: `https://bibsys-almaprimo.hosted.exlibrisgroup.com/primo-explore/search?vid=HIO`

3.3.1 Prototyping in practice

This activity is a central element of this thesis, as it plays a role in answering the research questions based on (1) the problem scope, and (2) findings derived from theoretical and practical knowledge. I adopted the research triangle by Fallman (2008) to explain how I intend to to use prototyping in my research. To summarize, the model has three areas:

- **Design Practice**: This is the area that consists of the techniques used as by design practitioners. Prototyping, along with brainstorming, evaluation, and data collection techniques are used to explore the problem space and answer the research questions. The work that is produced in this area connects back to design exploration.
- **Design Exploration**: This area is concerned with the problem scope and research question. My motivation is to explore how the threshold to introduce digital fabrication in arts and crafts is perceived by teachers. The result of the work in this area generates suggestions on how digital fabrication can be introduced to art educators, which can be found in Chapter 7. Possible answers to my research questions will be based on the work done on other areas.
- **Design Studies**: The area concerned with the origins of this thesis. This is rooted in theoretical and conceptual knowledge, with the latter pertaining to discovering the underlying topics of teaching digital fabrication from the users' standpoint. I use my findings from the literature review and previous papers on the current state-of-the-art education in arts and crafts in Norway.

To summarize the prototyping process, I gather theoretical knowledge rooted in the research questions (design studies), on which I use to explore the needs of the users, providing me with conceptual knowledge. Finally, I create the solution (design practice) using the design activities and evaluate them. All work from the other areas will diverge back to the research question and problem scope (design exploration). Figure 3.3 illustrates the relationship between each method used to explore the problem space.

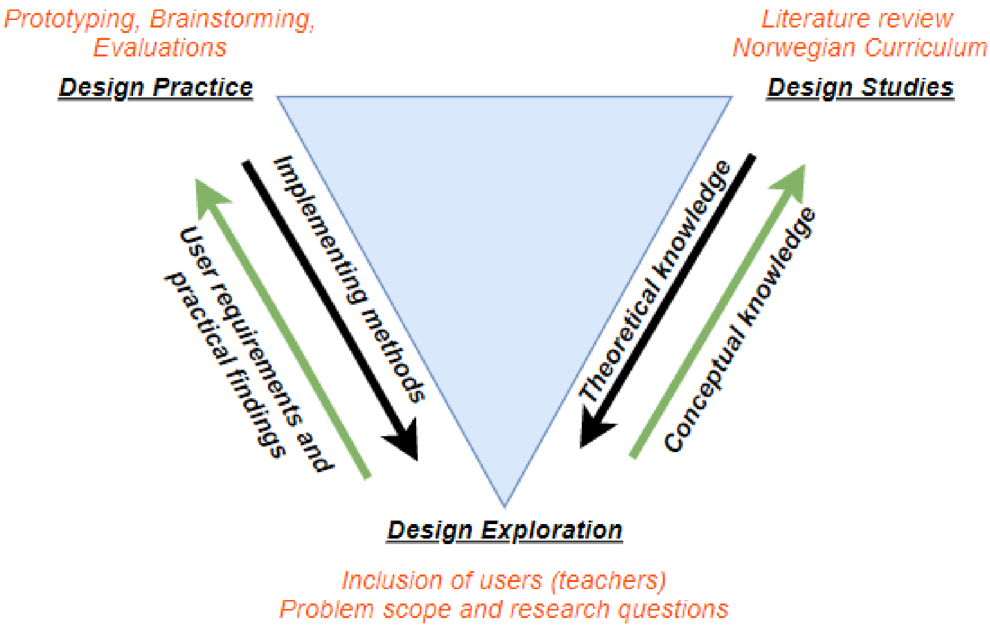

Figure 3.3: The process towards prototyping in this thesis adopted from the research triangle model by Fallman (2008).

In the context of this project, I intend to create a prototype based on the results from the activities within design practice (Fallman, 2008). In addition, this prototype will function as the product of the design step and the artefact to be evaluated when applying the proposed model of RtD by Zimmerman and Forlizzi (2014) in Section 3.1.1.

As mentioned in Section 3.1.1, the evaluation, and thus reflection of the prototype for data inquiry will result in the development of the final solution, which can be found in Chapter 5.

3.4 Brainstorming

After collecting data from the interviews and evaluation of the first prototype as described in 3.3 I would have a sufficient understanding of the root of the problem space. The project would be at a point where it is natural to start brainstorming design concepts based on the knowledge I have gathered. Although it is often used in the early or middle stages of product development, brainstorming aids in producing ideas to solve specific problems (Wilson, 2013, pp. 4-6). In this thesis, I use this method in Section 4.8 to assess the formation of the prototype, based on the knowledge I had obtained from the design activities performed prior to prototyping.

3.5 Data Collection and Evaluation

As mentioned earlier, the exploratory nature of this study points towards a qualitative approach. As I have already addressed the project's purpose in relation to the first step in the proposed model by Zimmerman and Forlizzi (2014), I outline a description about the users that are involved in this process for which the solution is intended for, including the procedure of participant sampling. I will thereafter describe the methods used to collect the data, as well as how I analyzed them.

3.5.1 Users

The users in this thesis will be defined as the subjects that will contribute and be affected by the product that is designed for them. Here, I will briefly describe their role and significance of this project.

Teachers

Teachers will be the primary user of this project as the transition to implementing digital literacy as a fundamental skill affects their field of work directly. As the curriculum changes, so does their teaching methods as they had practiced their work at a time when technology has not been the main focus. Additionally, teachers must be able to facilitate their students with the limited sources provided by their local school. Depending on the age and education background, teachers may differ in their practice. It is therefore important for this thesis to investigate their needs.

Students

The scope of the research will focus on children from the 7th to 10th grade. As mentioned in Chapter 1, children born in the previous decade will have familiarity with the technology relatively faster then those from previous generations. However, they require an introduction to programming and digital fabrication to meet the demands of policy makers. Another issue is that most programming platforms are provided in English, which creates a need to be introduced to programming in formal settings such as schools. Although the solution will be primarily used by teachers, students can be affected by how the teaching material is introduced to them.

3.5.2 Participant sampling

According to Morse (1991), the selection of samples are crucial to the knowledge needed for further research. With that in mind, the study requires qualitative data from potential users of the solution. Therefore, selecting art educators can aid the project in obtaining data that is representative of teachers in arts and crafts. Morse (1991) adds that there are no conclusive guidelines when it pertains to the number of samplings in qualitative research. Tuckett (2004) and (Creswell and Creswell, 2017, pp. 304-305) supported this by implying the importance of in-depth data from the samplings over the number of subjects.

Optimally, the project would also benefit a sampling of subjects consisting of two groups: experienced teachers and preservice teachers that specialize in art education. This is to gain an overall understanding of the perspectives from different generations. In total, 6 participants were recruited. Out of the 6 participants, 3 of them are experienced teachers while the remaining 3 had graduated from teacher education two years ago and are currently practicing their work in schools.

3.5.3 Semi Structured Interviews

Semi-structured interviews can be characterized as face-to-face interactions between the researcher and the participant (Creswell and Creswell, 2017, p. 305). Contrary to structured interviews, a semistructured interview can balance between specific and open-ended questions for an in-depth exploration of topics, making it valuable for qualitative research (Schmidt, 2004). Another advantage of this approach is that it creates grounds for contextual inquiry in the early stages of the research work (Raven and Flanders, 1996).

As the lead investigator in these interviews, I adhere to the guidelines from Rogers et al. (Rogers et al., 2015, p. 270). This includes neutral behavior, engaging with the participant, and avoiding leading questions.

3.5.4 Preliminary interviews with teachers

In this thesis, preliminary interviews were used to explore the teachers' perception of digital fabrication in arts and crafts. Furthermore, it functions as part of step 2 (design) in relation to the proposed plan from section 3.1.1. Furthermore, the findings from this activity will aid in addressing the first subresearch question, which will investigate the implications of the changes made by policy makers.

Planning the interviews

This was the first session of interviews conducted in relation to step 2 of the RtD process from Section 3.1.1. At this point, I developed an understanding of the literature concerning digital fabrication and its relationship to the educational sector. With that in mind, I wanted to explore the problem scope in practice by conducting interviews with relevant users, which in turn directs me towards an approach that can generate a useful prototype.

Performing the interviews

I performed three interviews with arts and crafts teachers working in Norwegian schools from the 3^{rd} to 10^{th} grade. The interview guide was inspired by the findings from the literature review from Section 3.2. I divided the interview guide in to three themes: (1) current practice, (2) creativity and engagement, and (3) use of digital skills in the subject. In the first theme, I had asked questions about the kind of projects conducted with the students. In addition, I asked about the materials and teaching methods used to achieve learning outcomes. On the second theme, I wanted the teachers to share experiences on how they promote their students creativity in the process of fabrication. The third topic investigated their use of digital tools in arts and crafts, and how it is applied in the classroom. The interviewees were asked to assess their level of use of digital tools in the subject. The preliminary interview guide created for this activity can be found in Appendix A.

The participants were informed about the background of the study prior to the interview via email. After we have agreed upon a common time, the interviews were conducted in a classroom at Østfold University College. Prior to the session, each participant received an outline of the themes that have been mentioned earlier. On average, each interview lasted approximately two hours. I asked follow-up questions on the topics that engage the teachers, to further conceptualize the requirements needed in the later stages of the thesis (Rogers et al., 2015, pp. 387). The interviews were recorded using hand-written notes using pen and paper. In this case, the objective of this round of interviews was to gain a better understanding of the problem scope in an non-exhaustive matter. This is why I did not see the need to take audio recordings in this session.

Analyzing data from preliminary interviews

As mentioned in the previous section, data from the preliminary interviews were taken using hand-written notes. After each interview, I transferred the notes to a computer, on which I had further written more detailed versions for each theme. After transferring and analyzing the notes, I outlined reoccurring topics that were to be used in relation to the findings from the literature review using grounded theory (El Hussein et al., 2014).

3.5.5 Project evaluation with teachers

Similar to the previous section, this part of the methodology pertains to the second step (design) in applying Rtd (Zimmerman and Forlizzi, 2014). The aim of this procedure was to investigate the threshold on the type of technology teachers can use in the subject of arts and crafts. I also consider this phase to operate as the "pilot" for what could be the final solution. By conducting this activity, I could further conceptualize how digital fabrication can appeal to teachers. This activity would also result in giving me an indication of how I should approach the final prototype.

Planning the evaluation

After analyzing the findings from the preliminary interviews with teachers along with the findings from the literature review, I conducted a practical review of existing fabrication tool kits and projects that have the potential to be used in arts and crafts, outlined in Section 4.4. I used the upcoming curriculum as my guide when I reviewed these projects. In this thesis, I base my example tasks on Micro:bit and its development platform, inspired by the BBC computing program as it provides students with a versatile product that can be used in multiple disciplines in STEM education (Carlborg and Tyrén, 2017).

I have focused on projects that complied with the following: Firstly, the relevance of implementation within the subject in question (arts and crafts). Secondly, I looked for projects that combine digital technology with traditional crafting methods such as cutting, folding, and drawing. In addition, it would be beneficial if the technology used in these projects helped up-heave the core of the task at hand.

After completing the practical review, I ended up with four different examples, with different variations on the use of technology and programming. The presentation of the tasks can be found in Appendix C. The variations differ in terms of difficulty level, ranging from just simply turning on the technology at the lowest level and to the possibility to implement programming at the higher end. This was to ensure that the teachers would be able to evaluate the projects based on the use of the technology by decreasing the threshold. I had also created a form for me to fill in the initial responses of the participants(teachers) for each example, which included follow-up questions. This can be found in Appendix B.

Performing the evaluation

The evaluations were conducted with four art educators. One evaluation was performed physically while the other three were performed virtually. I had first informed the participants about the purpose of the study and sent the projects digitally in case there are disruptions in the virtual meeting system. I began the session by outlining areas within the curriculum that focus on digital fabrication in the subject of arts and crafts, as it is still a recent change for some teachers. This was followed by an introduction to the microcontroller and the specifications it had, as it can be used with the projects I had created for the evaluation.

I then presented one project, explaining the aim of conducting it, the materials needed, and the potential learning outcomes that students gain after completing it. The teachers then provided their assessment and hand-written notes were taken in the process. The nature of the sessions resembled the "think aloud" procedure. The follow-up questions focused on (1) the usability of the project, (2) which grade level would be best suited for, and (3) suggestions on what should be adjusted. At the end of the evaluation, I asked each teacher if they had suggestions on what can be further developed to meet their needs. Each session lasted an hour.

Analyzing data from the evaluation

As mentioned in the previous section, I had taken hand-written notes which were then expanded after each session. A qualitative approach was used to analyze the data using grounded theory. The data collected from the teachers were used to gain a further understanding of how the final solution should be formed. I created categories with words and suggestions on how I as a researcher can develop a prototype that is optimal for the practice in question (arts and crafts).

3.5.6 Prototype evaluation

After developing the final prototype, I conduct the second session of data inquiry with teachers that have evaluated the solution. This is in the form of a qualitative evaluation of the suggested solution. This section operates as the third step in applying Research through design (Zimmerman and Forlizzi, 2014). Furthermore, the work that results from this activity will address the second subresearch question stated in Chapter 1.

Planning and design

This session will build upon the knowledge obtained from the theoretical background, findings from the preliminary interviews, and results from the project evaluation. As for the sampling of participants in this activity, I acquired four arts and crafts teachers, with varying degrees of experience practicing their work in both schools and higher education(teacher education). To provide consistency with my work, two of the subjects had already participated in the preliminary interview, while three of the teachers have participated in the project evaluation. Based on the findings from these previous exhibits of data, I create my first iteration of the suggested solution that will be tested and evaluated by teachers practicing arts and crafts.

Performing the prototype evaluation

Four participants took part in the evaluation of the final prototype. Similarly to the project evaluation, I inform the participants of the aim of the study, while simultaneously sending them the prototype. The subjects would then be given a certain amount of time to work through the prototype in their spare time. They have also been given the option to ask questions during this phase, to clarify any unexplained issues.

I have also created a set of questions that the teachers will answer during the evaluation of the prototype, which can be found in Appendix D. The questions focus on the research questions. I asked mainly on the level of interest the prototype provides for the teacher if they were to use it in their practice. The question of most interest would be if the solution is applicable to their work and that it meets their needs. Questions about the difficulty level and realistic use have also been noted. At the end of the evaluation, I gather suggestions on how to improve upon the first iteration, and what should be supplemented/removed.

Analyzing data

Handwritten notes were taken, which were expanded to detailed notes after each session. The analysis approach of this method was similar to the project evaluation, which was of a qualitative nature (grounded theory). I had created a table of the documented experiences from the evaluations, where I summarize the important themes and suggestions that will be used for discussing the findings in Chapter 7.

3.5.7 User-centered approach

Design practitioners argue that it is important to include users in the development process (Rogers et al., 2015, pp. 43-47). As I explore the needs of the teachers, I feel that it is natural to adopt a form of user-centered approach throughout my research. Rogers et al. explained that the level of user involvement is flexible, depending on what is intended (2015). In my case, I intend to involve art teachers on three occasions. At the earliest stage of my research, I involve teachers in my preliminary interviews. During the project evaluation, I would also involve teachers to collect the data needed to develop my final prototype, which will also be evaluated by the primary users. The idea behind this approach is that we as design practitioners, must ensure that teachers have control behind the technology in its simplest form. There would be no point in developing new and advanced tools if it is challenging to use existing tools today. It is an interesting notion that will be discussed in Chapter 7.

3.6 Ethical Considerations

Naturally, in any research, one must be aware of the ethical implications when conducting scientific methods with subjects. As I am working on my project on behalf of Østfold University College, I adhere to their research ethics guidelines [2]. The guidelines state that I, the main researcher, must bear the responsibility to ensure that my work is within general ethical principles. The institution has created a checklist, to which I have followed throughout my work. Furthermore, research must have a beneficial value to society and avoid controversial implications, while still contributing to relevant research fields. The work from this project has no harmful implications to society.

The involvement of subjects concerns the process of inviting potential users for testing and inquiring data. I have obtained informed consent electronically from those I have collected data from, providing them the details of the project in a briefing session before and after data collection. This was applied to all methods that implied collecting data(interviews and project evaluation). In addition, I ensured the participants that they will have anonymity throughout the entire period this thesis has been conducted.

During data collection, I constantly asked myself the key question of *"what kind of data do i need to answer my research questions?"*. The Norwegian Centre for Research Data requires researchers to send in an application in the case that any personal data was used in the data collection process [3]. I had taken the test, registering that no personal information would be collected for this research. In my data collection methods I had used with the teachers, I had no need to register any personal data on my subjects as I had relied on handwritten notes as mentioned in Sections 3.5.4, 3.5.5, and 3.5.6. Based on the guidelines from Østfold University College, the research performed in this thesis are within ethical principles.

[2] Research Ethics - Østfold University College: https://www.hiof.no/for-ansatte/english/work-support/research-support/research-ethics/index.html

[3] Norwegian Center for Research Data, check test: https://meldeskjema.nsd.no/test/

3.7 Summary

This chapter has presented Research through Design as the core methodology for the project work. Furthermore, this thesis will utilize the field approach of RtD, using four of the five steps adopted from the proposed model by Zimmerman and Forlizzi (2014), as shown in figure 3.2. I deem it necessary to provide structure while conducting research of this kind. As I take a qualitative approach to inquiring data from the methods presented in this chapter, the analysis will be conducted in a similar matter. Subsequent sections describe the design activities in relation to the adopted five-step plan. There were three participants in the preliminary interviews, four in the project evaluation and four in the evaluation of the prototype. The chapter concludes with an evaluation of the ethical considerations taken to perform the project work.

Chapter 4

Prototype Design

This chapter goes through the design activities leading to my final prototype in the form of a web based application, developed to support art educators implementing digital fabrication in their practice. The final prototype will also provide further exploration of the research questions defined in Section 1.2.1. The process that led up to the final prototype is based on the five-step model of research through design as explained in Section 3.1.1. This chapter also serves as preliminary results of the design activities performed leading to the final prototype.

As explained in Section 3.1.1, it is important to provide detailed explanations when applying these methods at each step (Gaver, 2012; Zimmerman and Forlizzi, 2014; Zimmerman et al., 2010). Which is why I will also explain my thought process between each method applied, as well as the directions I take towards the final prototype.

This chapter begins with an initial concept definition behind the prototype. This is to clarify the goal of prototyping, rooted in the research questions. Following that, I review my findings from the preliminary interviews, as they provide contextual knowledge, establishing requirements. This chapter will then present a practical review of digital fabrication tools and projects that can be used in the subject of arts and crafts. In addition, the same section will also Using the findings from the practical review, the next section will look at the evaluations made by potential users. The following section looks at my thought process towards creating the prototype. This is in the form of brainstorming with the knowledge I had obtained from the previous sections.

4.1 Initial Concept Definition

In the early stages of applying RtD according to the five-step model (Zimmerman and Forlizzi, 2014), it is suggested to conduct a literature review as suggested in Section 3.1.1. The work that has resulted from this part of the research can be found in Chapter 2. In this literature review, I have covered the uprising of digital fabrication, looking at essential concepts such as constructionism, maker culture, and the formation of fabrication labs. I had also explored the relationship between education and computing, as well as the implications of introducing digital fabrication in schools. Arts education in Norway was also an important element to review, as it provided an understanding of the value this subject brings to society. I identified the underlying issues of incorporating technology in arts education.

The findings from the literature review shaped my understanding on context of the educational system. However, what of the current practice in schools today? Despite my current knowledge of the literature, this thesis would benefit from exploring the real life practice of art educators. On this basis, I conducted semistructured interviews to gain an in-depth understanding of how digital tools are used today, especially in Norwegian arts and crafts. In addition, I wanted to explore the traditional activities they would apply. This is to look for areas that can be integrated with digital tools using my prototype. Now that I have an overview of previous work for my thesis. I proceed by investigating the current context of how the subject is being practiced in the next section.

4.2 Findings from preliminary interviews

In this section, I present and briefly analyze my findings on the use of digital tools in arts and crafts retrieved from semistructured interviews. Two of the teachers have worked intensively with children from the 5^{th} to 10^{th} grade, while the third one has worked with children from the 5^{th} to the 7^{th} grade. The choice of interviewees was aimed towards teachers that have familiarity with the new curriculum. The aim of the interviews was to explore the core concepts of arts and crafts in education, and the approaches used to achieve learning outcomes. I also explored their use of technology and access to digital tools. The interviewees were asked to assess their level of use of digital tools in the subject. The questions used in this study can be found in the appendix section.

Findings from two interviewees show that their teacher education has not been able to include digital fabrication. In other words, they do not have the required digital competence to introduce the technology, which creates a threshold to implement it in their practice (Imsen, 2020). One interviewee explained that most of the education has been directed towards traditional crafting methods and pedagogy. When it came to the use of other digital tools, all three interviewees said to have used multimedia editing programs. It seems that the technology itself has not been used to construct products, but rather used to retrieve and present information using programs (Sjøtun, 2013). I recognize that this is a crucial gap that needs to be addressed in the production of the prototype.

All three interviewees have expressed that it is important for students to understand how production materials can be used. They value sustainable creativity through meaningful construction. For instance, repairing objects (sewing damaged clothes, etc.) or creating useful products that children will appreciate. One interviewee described one setting where the students were given a task in reproducing a famous work, requiring them to investigate using a computer and presenting their product using Microsoft PowerPoint. This has been also the case across related work, where digital media has been the focus within arts and crafts, ranging from creating commercials to photography and film, and the development of interactive websites and blogs (Lepperød et al., 2013; Traavik et al., 2009; Sæthre-McGuirk, 2017).

According to two interviewees, there is a discrepancy in what the curriculum demands and what has been done in practice due to the lack of digital competence, correlating with the claims made by Lyngsnes and Rismark (2017) on the role of the teacher. Two interviewees suggested that today's computer scientists should shift their careers to the education sector to effectively train all schools across the nation. However, to the extent of my knowledge, there is no definite way of knowing how long it can take before policy makers can take such initiative. There is also a lack of resources directed towards digital fabrication in arts education. One interviewee expressed the lack of funding to purchase 3D printers. Two interviewees were positive to use technology in their teaching, however they also express that they do not know where to start. Based on these findings, the framework set by policy makers has not been realized, indicating a need to facilitate the introduction of digital fabrication in a way that can be comprehensive for teachers to use while achieving learning outcomes. In addition, the solution should also be within financial constraints, meaning that it should be cost effective.

The interviewees were asked to provide examples of teaching activities that they teach to their students. I was looking for possible applications to integrate technology. All three interviewees have projects where students create models or figures using paper, plastic, and cardboard, learning how to put them together using different types of adhesives. One interviewee teaches students how to sew and repair clothes. I had documented one case where they created seat pads, belts, straps, and bags using old clothes. Two interviewees described projects where their students create models based on feelings or themes. One interviewee had a request to explore if digital tools can create entities that children can interact with.

4.3 Defining the goal of prototyping

According to the research triangle model I had adopted from Fallman (2008) in Section 3.3.1, I have obtained theoretical knowledge in the area of *Design Studies*. In addition, I have managed to gather conceptual knowledge from the preliminary interviews with potential users. The requirements that I have collected are as follows:

- There is a need to develop a solution that can support the use of fabrication tools.
- The solution must comply with the new curriculum for arts and crafts.
- Furthermore, the solution should not strain the allocated resources that the teachers have.
- In addition to other factors, it is important that the solution should have a low threshold in terms of usability.

I wanted to provide the teachers with something tangible as arts education is a practical subject. My first thoughts were to look at existing solutions and look at small computing units with electrical components (lights, motors, etc.) that could be programmed. The next section explores the relevant technology that will be considered to progress in the prototyping process. As I had discovered in Section 4.2, a lack of technical support can be addressed if the technology was reintroduced in their context. In this case, if we can find projects that combine traditional crafting and digital fabrication, we may be able to lower the threshold for teachers.

4.4 Practical review

In this section, I present relevant practical tools within computing fabrication applicable in the realm of education. This begins with my selection of technology, followed by a review of existing tool kits. Finally, I give an overview of projects and tasks that can be relevant to use in today's art education.

4.4.1 Selecting a suitable digital tool

Prior to this review, I deemed it appropriate to use a fabrication tool that was relatively inexpensive, yet easy to interact with for beginners. This has led me to select the Micro:bit. Furthermore, I was inspired by a study by Carlborg and Tyrén (2017) where they incorporated programming in Swedish schools using Micro:bit. The technology is recognized as a low-cost computer that can provide a multitude of projects. It functions also as a stepping stone towards complex platforms such as Arduino, ESP32, and Raspberry Pi as it can connect to sensors along with its respective API [1].

The Micro:bit's applications within education support the benefits of physical computing, which could be relevant within the Norwegian curriculum (Sentance et al., 2017). In addition, there are multiple development environments that support coding with the microcontroller. Furthermore, the Micro:bit has been associated with the maker movement as it offers an *inclusive introduction to coding and making* to students and teachers, turning them from consumers to content creators (Austin et al., 2020). Sentance et al. (2017) argues also that the Micro:bit can connect to topics such as arts by creating interactive products as the technology is of tangible nature with possibilities for creativity.

Micro:bit microcontroller

The Micro:bit includes the following features as shown in Figure 4.1:

- Two buttons (A & B) that are programmable along with a reset button.
- A display matrix to show patterns and figures (25 LEDs in total).
- Thermometer for measuring the temperature.
- USB connector along with a battery socket for portable projects.
- The ability to determine the level of light.

[1] BBC Micro:bit unveiled: https://www.bbc.com/mediacentre/mediapacks/microbit/

- Three I/O ports in addition to voltage(3V) and ground(gnd) to use when programming towards motors, sensors, and extensions of the Micro:bit.
- Accelerometer to detect the movement of the device (if flipped or shaken for instance.)
- Is able to connect to Bluetooth devices. It can also communicate with other Micro:bit units.

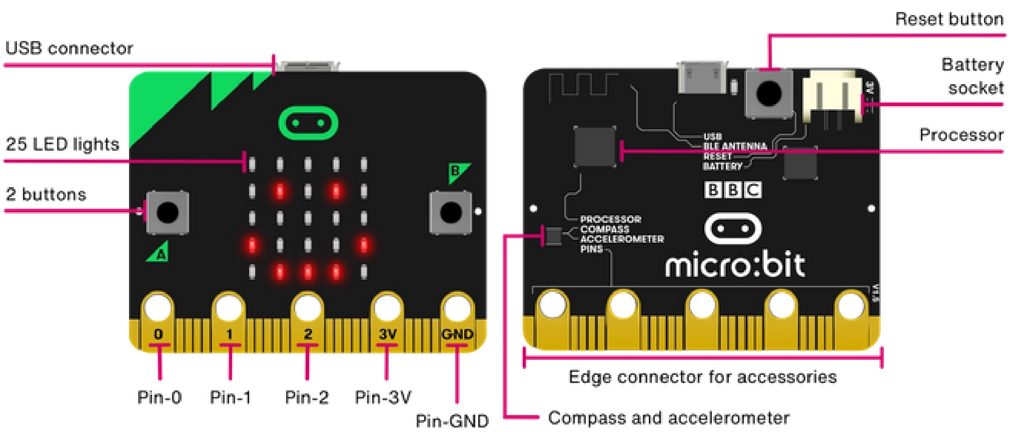

Figure 4.1: Specifications of Micro:bit.

As mentioned earlier, the Micro:bit can be programmed in different environments, however, in this project, I will be only focusing on the original Micro:bit editor provided by the creators of the technology. The editor, as shown in Figure 4.2 is an online platform in which users can use JavaScript or Block programming, which can lower the threshold for programming for children in primary schools. In addition, the editor can be used across different devices regardless of the operative system (Linux, Windows, IOS, and Android), meaning that the only requirement needed to use the editor is access to the internet. This can appeal to smaller schools that do not have the economy to invest in state of the art fabrication machines.

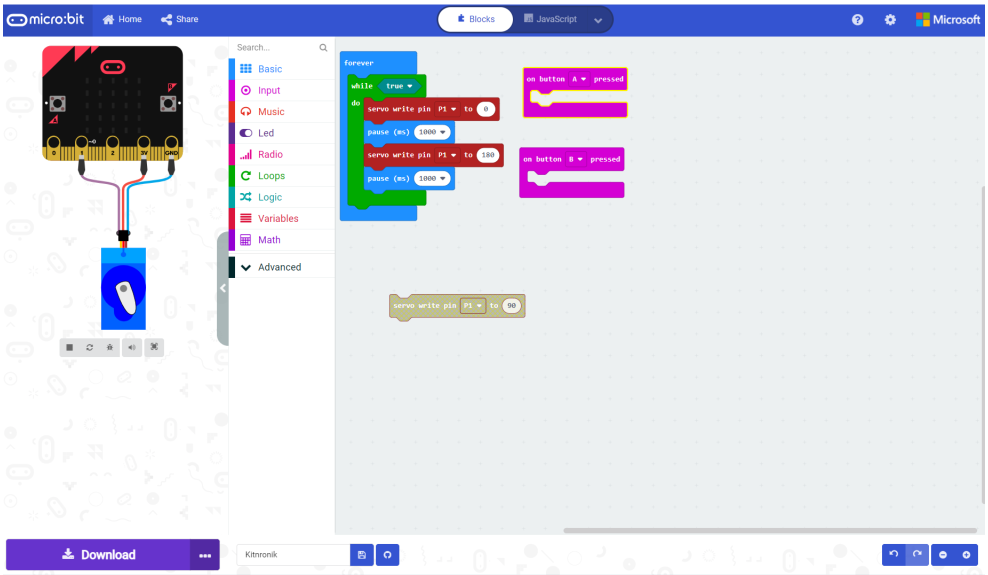

Figure 4.2: Micro:bit's own editor in which the programming occurs. The user has the option to use Blocks or JavaScript.

After the first iteration of Micro:bit had been launched in 2015, a series of toolkits were introduced to the general public with extensions to the Micro:bit that are used for specific projects that will be highlighted in 4.4.2.

4.4.2 Existing tool kits for Micro:bit

In this part, we look at existing tool kits to get a better overview of the potential projects that can be done in schools. Most tool kits using Micro:bit normally come with a standard set of components. Figure 4.3 shows what a typical starter set consists of: such as buzzers, motors, and LEDs with ranging colors. They are also accompanied with a battery pack, breadboards, and wires for configuration.

Figure 4.3: The assembly of the sensors and components from a typical Micro:bit toolkit.

When looking for tool kits, a general observation that was made was the variety of project-based sets that were available for purchase. Some tool kits are aimed towards smart cars or screens while other tool kits are themed based, such as IoT systems or digital pets, for instance, providing the consumer with a model that can be assembled and programmed using the Micro:bit. There are certain kits assembled by maker businesses that also provide learning platforms in the form of wiki pages, such as Elecfreaks [2]. Similar to Elecfreaks, TinkerAcadamy[3] also has a dedicated kit accompanied with examples and starter projects from their own learning platform. Figure 4.4 shows the components of the tool kit provided by TinkerAcademy.

[2] Elecfreaks learning platform: https://www.elecfreaks.com/learn-en/
[3] TinkerAcademy: https://tinkercademy.com/

Figure 4.4: TinkerAcademy's tool-kit for Micro:bit.

Some of the common projects that are in their learning platform guides the users through most of the sensors. For instance, to understand how to use the buttons and buzzer, there are projects that encourage the user to create a "music machine", where the user can program a specific tone to play on the buzzer using the buttons as shown in Figure 4.5.

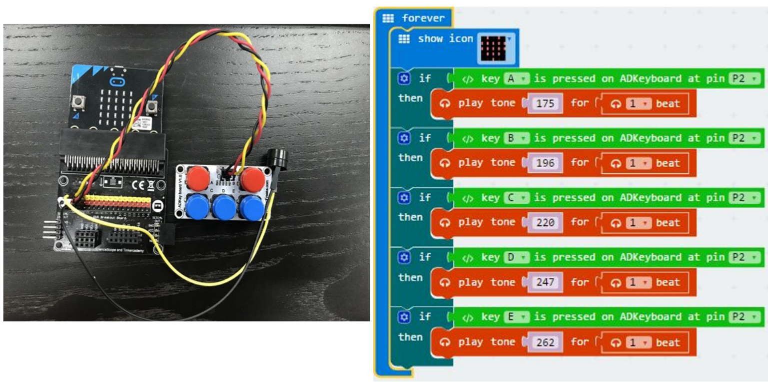

Figure 4.5: A music machine using a buzzer and buttons - TinkerAcademy

4.4.3 Projects and tasks within crafts using Micro:bit

At first glance, it was difficult to find specific projects that met the criteria I have set as it seems that there are few of them that have a combination of traditional crafting methods and digital tools, as most projects focus mostly on the sensors used, not necessarily upheaving techniques used in the classroom. However, there are projects that were within the criteria which can be implemented in schools.

Lightbox and Lanterns

This project is about creating a simple lightbox[4] using an LED strip, powered by a Micro:bit. In practice, one would need to open and cut the box to wrap it with a translucent layer (tracing paper) which can be used as a canvas for decoration or expression as shown in Figure 4.6. LED strips can have different colors, so it is possible to use that to further enhance the drawing on the tracing paper.

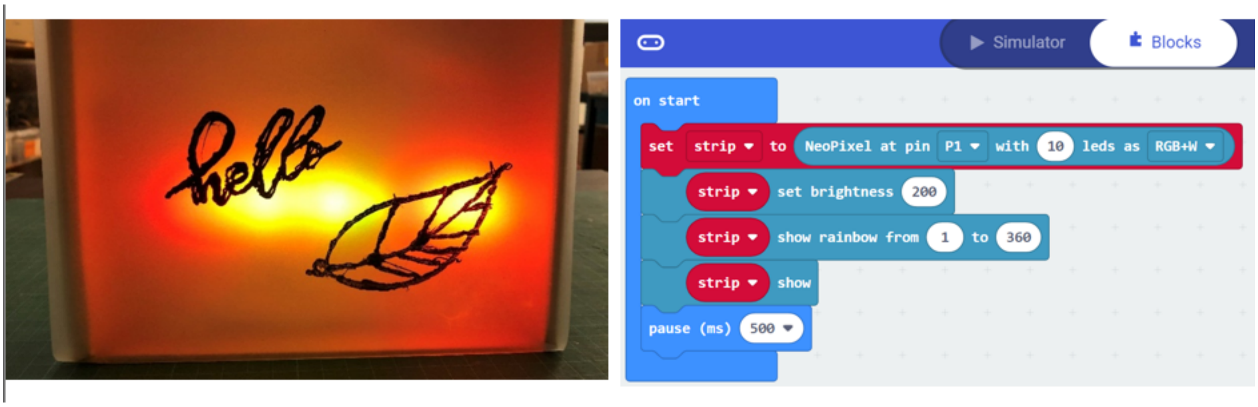

Figure 4.6: Lightbox using an LED strip and Micro:bit.

There is a similar project that takes another approach where one needs two pieces of paper instead of a box[5]. The project provides a template of how to cut the pieces of

[4] https://lets.gethacking.com/activities/lightbox
[5] https://www.instructables.com/Make-a-PaperCard-Lantern/

paper to form a lantern as shown in Figure 4.7. In other cases, one can use things that are not in use, such as empty jars or containers, as a possible argument for sustainability.

Figure 4.7: Micro:bit light source using two pieces of paper.

Dice game

Figure 4.8 shows the Micro:bit being used as a smart dice on a board created with paper and colors [6]. This project separates the technology and level of craftsmanship, however, both are used together to create a dice game.

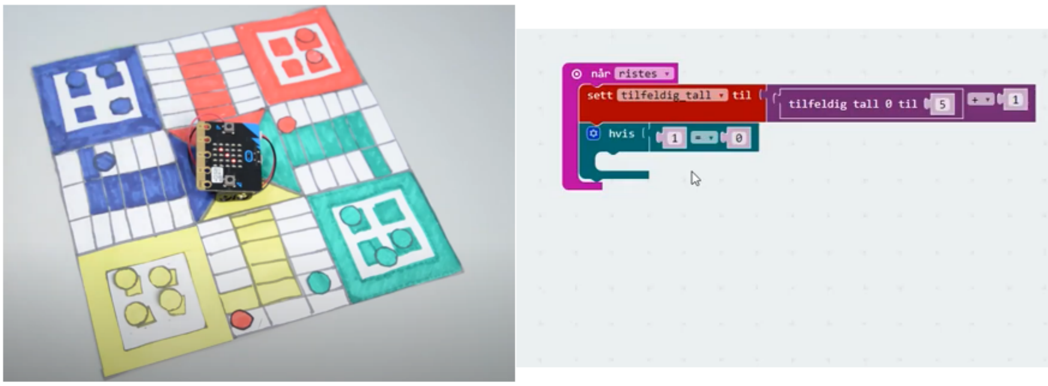

Figure 4.8: Micro:bit dice game

[6] Dice game code: https://makecode.microbit.org/68432-62813-34337-62362

On one hand, the user gets to be creative with the design of the board, to which the "dice" will be used for the technology is being programmed to create context for the game. One thing to take away from this is how Micro:bit can be used for entertainment. The simplicity can appeal to classes that do not have enough equipment. In addition, it is possible to create other versions of games with the Micro:bit in the center.

Fabrics and Wearables

There are projects in which we can use fabric and textile fabrication to provide context for the Micro:bit. Figure 4.9 shows a project in which the Micro:bit operates as a smart belt that uses its built-in accelerometer to show information such as images, temperature, and geographical direction [7]. In this context, it is possible to also turn it into a simple smartwatch as well.

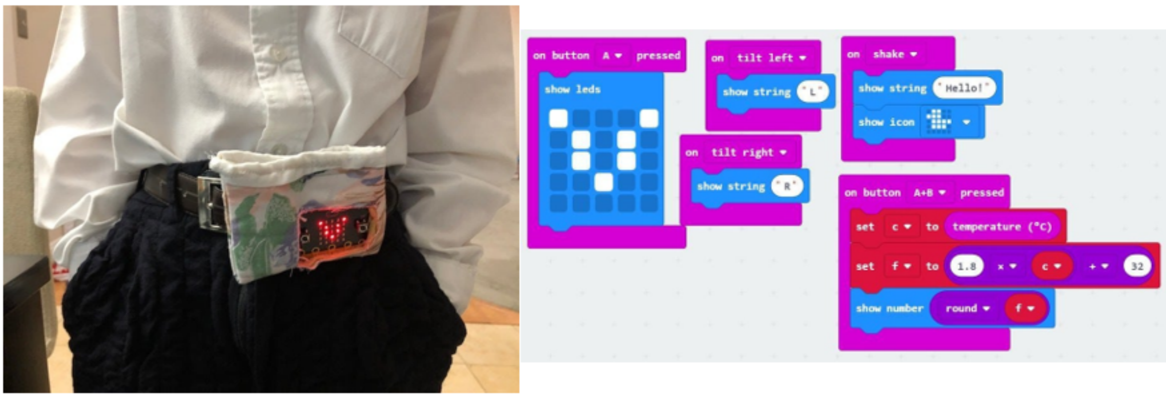

Figure 4.9: Smart belt using Micro:bit and fabrics sewn together. From LKK[8]

Figure 4.10 illustrates a project in which the students create their own image using fabrics and sewing in LEDS with conductive thread to explore how circuits work [9]. The lights can be used as the animal's eyes. Other applications can be: a wearable

[7] Smartbelt, Instructables: https://www.instructables.com/circuits/wearables/projects/
[9] Combining fabics with technology: https://oppgaver.kidsakoder.no/microbit/e-tekstil/e-tekstil

material with LED strips as borders. This project can at least be used as an introduction to wearables. This task illustrates the potential of combining fabrics with fabrication technology.

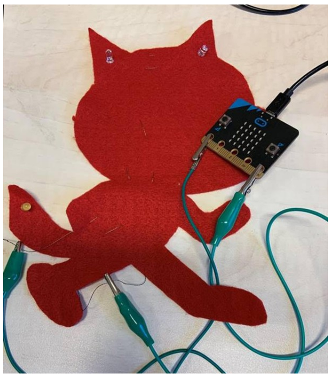

Figure 4.10: Micro:bit project to create a figure with lights using conductive thread

Useless robots

This project is more detailed as it is a long-term educational module used at a school, specifically for 7th graders [10]. The goal of this group project(2-3 students) is to create a simple robot that can solve an annoying problem. Students are to first brainstorm a simple, yet meaningless problem that can be solved using technology and how their robot can operate to fix it. They are to design and prototype the robot and create the program using the available tools. In their case, they had cardboard, Micro:bit and servo motors available. Figure 4.11 shows a result of one of the simple robots.

[10] Useless robots: https://dybdeundervisning.no/produkt/ubrukelige-roboter-med-microbit/

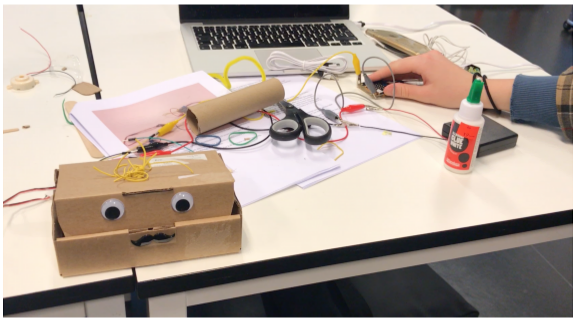

Figure 4.11: Robot project using servos programmed by Micro:bit

Paper Mechatronics & Papermech

Paper mechatronics is a relatively new interdisciplinary design method that originated in 2014 that explicitly combines traditional papercrafting with the roots of digital fabrication, namely, mechanical engineering and physical computing.

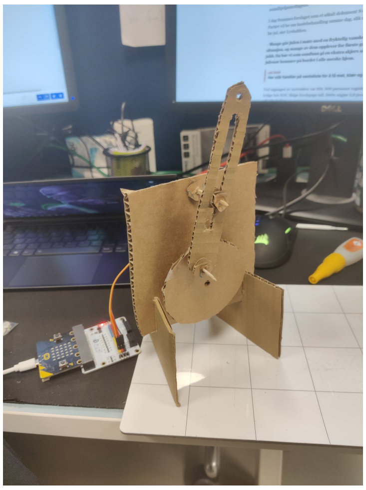

Figure 4.12: A recently fabricated crankshaft using cardboard and Micro:bit servo.

According to one of the pioneers of this medium Oh (2015), papercrafting invites a diverse range of people to experiment with inexpensive equipment and implementing technology and simple mechanics can enlarge and upheave interactive projects with low cost equipment. Figure 4.12 shows that paper mechatronics can be used within digital fabrication [11]. The parts needed to create the shaft were from a template created by Papermech. Papermech [12] provides teachers with detailed lesson plans on how to create gears, cranks, and other mechanical parts using cardboard, wood, or paper. Combining this with servos gives creators good opportunities to visualize interactive work.

Paper Pocket Pets

Paper Pocket Pets by Stigberg et al. (2019) was aimed towards empowering children to apply digital fabrication in a playful matter. The concept is inspired by Tamagotchi, Fingerlings, and Hatchanimals. It allows children to create customized pets that can interact with the owner and other digital pets. It combines traditional crafting methods like paperfolding, combining components, and origamini as shown Figure 4.13. Furthermore, the modular nature of the kit allows children to continue developing on their craft. The project is published with a guide on how to create them using Micro:bit [13]. In the case of my thesis, I recognize that this concept, with its modularity can be scaled depending on the class the teacher works with. This seems suitable for the earlier grades in the K-12 program (5th and 6th).

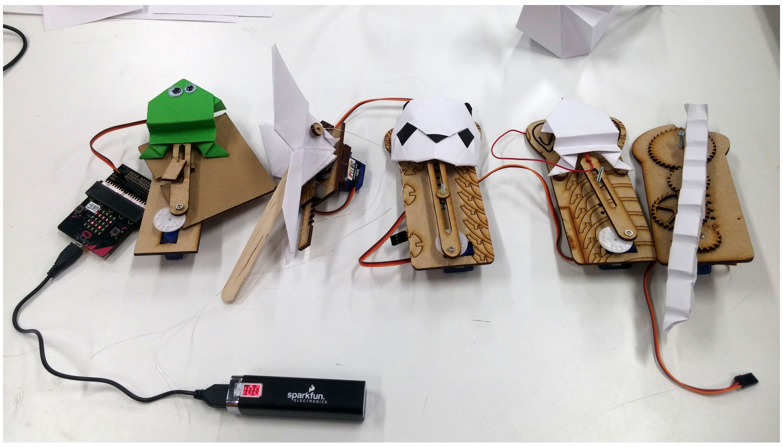

Figure 4.13: Paper Pocket Pets by Stigberg et al. (2019)

[11] http://www.papermech.net/wp-content/uploads/2019/06/Crankshaft-placemat.pdf
[12] http://www.papermech.net/lesson-plans/
[13] Guide on how to create Paper Pocket Pets: `https://www.instructables.com/Paper-Pocket-Pets/`

4.5 Framing the prototyping goal

Table 4.1: Summary of potential projects after practical review

Project suggestion	**Tools along with Micro:bit**	**Possible Outcome**
Name Tag	Fabric, paper and adhesive	Introduce programming. LED matrix.
"Smart" Lantern	Paper/cardboard	Introduction to LEDS.
Pop up puppet	Servo motor, template for crank	Mechanical movements.
Digital Wearable	Fabric (textile manufacturing)	Combine fabrics with technology.
"Neon sign"	Fabric, LED, Conductive thread	Combining fabrics with technology.
Paper Pocket Pets	Paper, motors, lights	Interactivity with servo. Sensors
Recreate Models	Paper/plastic, motors, lights	Sustainable creation of value.

Table 4.1 summarizes a list of possible projects to explore with teachers. These projects are based on what I define to be relevant tasks for students in K-12 art education. They combine traditional fabrication techniques that teachers use in their practice with digital tools, which can accomplish two goals. Firstly, they would be accepted in the new curriculum, as they involve different levels of programming and interactivity. Secondly, the level of technology incorporated would not be overwhelming for teachers, provided that they get support at initial use.

Even though the projects are available, I still recognize that the threshold to use them is uncertain within the education sector. In addition, it is also not given that these projects are suitable based on my research. The digital competence mentioned in Section 4.2 should also be addressed. There is also a need to address how these digital fabrication projects can be introduced to the teachers in a matter that can encourage them to practice it themselves.

4.6 Project Evaluation

This section will present the teachers' perspective on the projects I had retrieved from the previous section. I begin by setting up educational projects based on a sample of digital fabrication projects. In addition, I had demonstrated the code needed to achieve specific functions. This is followed by the format I have presented the projects to the participants. As I have mentioned in Section 3.5.5, I manged to conduct one evaluation with a participant in a physical location, allowing the participant to interact with these projects. I will then present the findings, which will result in suggestions and feedback that will be used in the formation of the final prototype.

4.6.1 Design for project evaluation

To get the most feedback from my participants, I have to present the projects with reference to the curriculum, more specifically, digital competence as a fundamental skill. Since the implementation of the new curriculum is yet to arrive, I intend to begin my evaluation by presenting the changes that apply to arts and crafts.

4.6.2 Sample projects

I have selected a sample of projects that vary based on the level of programming and assembly variation in crafting techniques. All projects use Micro:bit and block programming. The following selection is as follows:

A: Wearable Name Tag

The purpose of this project is to introduce programming with Micro:bit using their LED matrix. The board will function as the face of the product. The children begin by creating the housing of the Micro:bit, using fabrics and incorporating sewing techniques. After the Micro:bit has been programmed, they can insert it on to the housing they had created. Here, the teacher is free to challenge their students to create belts, watches, headbands, and footwear. To increase the level of programming, the Micro:bit can be further developed to communicate with other units. The students can also use the sensors integrated within the unit (accelerometer, temperature, microphone, buttons).

Figure 4.14 illustrates an example of a wearable with Micro:bit. The students would need dedicated battery packs to make their product portable.

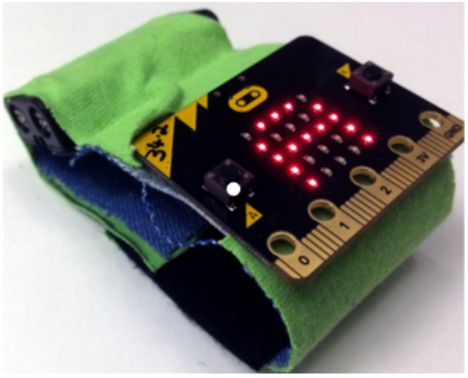

Figure 4.14: A wearable with a Micro:bit functioning as a watch.

B: "Smart" Lantern

The purpose of this project is to incorporate LED components using Micro:bit. This would also function as the first project where the students would have to learn how to configure electrical components. It begins with the students creating a lantern with reusable material(newspaper, shoebox, etc.), and customizing it. The students can use programmable LED strips as shown in Figure 4.15 to illustrate color transitions.

Figure 4.15: Programmable LED strip.

C: Rotating Fan

This project introduces the use of a servo motor. Similar to Project B, the students are challenged to perform technical configurations. There are possibilities to create moving illustrations or functional models. Students are encouraged to bring reusable plastic items, similar to what is shown in Figure . Although it does not seem to be the most aesthetic project on this list, the intention is to provide a stepping stone to potential applications where the motor can be useful to use.

Figure 4.16: Using a plastic bottle to create a fan using a motor.

D: A Digital Pet/Robot

Inspired by the work of Stigberg et al. (2019), this project is rich in the combination of traditional crafting and incorporation of technology. Similar to Project A, the micro:bit functions as the face of the model. Furthermore, this project will allow students to implement interactions with the built-in sensors. The students begin by building the model of choice, customize their creation, and then proceed to program the necessary functions on the microcontroller. The teacher is free to dispense the raw materials available and decide the theme of the project. Figure 4.17 shows an example of a pet robot with Micro:bit and a battery back inside the model.

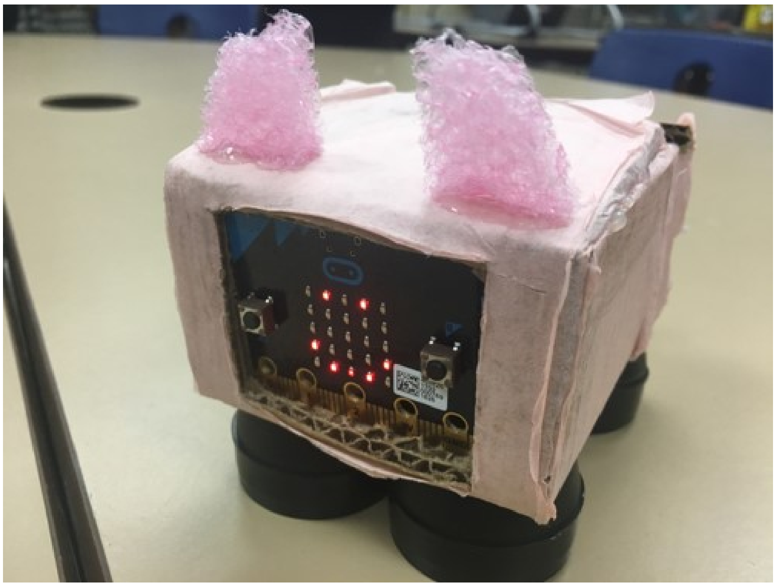

Figure 4.17: Pet robot with Micro:bit.

4.6.3 Findings from project evaluation

First, I will summarize the evaluations on the projects that have been presented to the participants. This part is important towards the final prototype, as I rely on potential users to determine which tasks are useful for further development.

Evaluating Project A

All four participants assessed this project to be interesting to apply in the classroom. It is a project they would be able to conduct, adding that the code needed to manipulate the display on the Micro:bit is understandable. One participant has however requested to provide future users with detailed descriptions on how to set up the Micro:bit. The freedom in choosing the wearable makes it easier for them to challenge their students to create products with variation. Two participants would adjust the difficulty of the project depending on the grade. One participant mentions that this project is suitable for cross-disciplinary topics, referring to an example where students create step counters to test their skills in physical subjects. According to another participant, there is value in the project as it can promote sustainability. The project is suitable for children from the 4^{th} grade and upwards.

Evaluating Project B

Similarly to Project A, this project was perceived to be flexible to all participants. For two participants, the task can easily be adjusted depending on the class and teacher. One participant sees the value of combining traditional crafting methods and programmable light. The remaining participants argue that it should be possible to create a similar product without programming. This is to put more emphasis on the product for the younger grades(2^{nd} and 3^{rd}). With older classes, programming can be encouraged. Unlike Project A, this project opens up to use almost any material (paper, plastic, and wood). All participants agree that this can open up to tinkering with different methods of joining parts. The project is suitable for children from the 3rd grade and upwards, with the teacher adjusting the difficulty. The lights can also be used for seatpads, an application that appealed to one participant.

Evaluating Project C

This is project with the least relevance to arts and crafts teachers. Despite its promotion for sustainable creation, the product itself does not express any crafting value for the participants. However, according to two participants, it would benefit cross-disciplinary topics with STEM subjects. For one participant, the motor itself can be used in other applications. For instance, a replica of a historical sculpture that can move certain joints.

Two participants deemed the project difficult to conduct and should be applied to lower secondary education (8^{th} to 10^{th}).

Evaluating Project D

For all participants, this project was interesting to use in the classroom. Similar to Project A and B, the flexibility of choosing the theme can challenge the students in a playful matter. There is little limitation to the types of materials one can use when creating these pets. One participant raised the notion that this project can be used to express the feelings of the creator and can even promote mental health. The advantage to this project for two participants, was the possibility of doing this as a group project, encouraging collaboration while saving resources in the process. There was a request to allow the Micro:bit to communicate with other units, a functionality that is possible within the development platform. The project is suitable for 5^{th} graders and upwards.

4.6.4 Finalizing the findings from project evaluation

The general impression from the participants was that the projects were relevant for arts education in Norway. This is in the context of the changes made in the curriculum. However, one participant argued that learning outcomes should not be the main focus, as it can be interpreted differently dependent on the teacher. This finding leads me to refer to the core elements of arts and crafts [14].

Three participants expressed that teachers in arts and crafts generally prefer tasks that are repetitive, however, they recognize that the attitude of practicing teachers is based on old traditions. The more concrete the instructions are, the easier it is to complete them. Furthermore, all participants wished for a detailed guide when first introduced to digital fabrication tools. Another issue is the language barrier between

[14] Core Elements for the subject of Arts and Crafts: `https://www.udir.no/lk20/khv01-02/om-faget/kjerneelementer?TilknyttedeKompetansemaal=true`

technicians and educators. Terms such as *programming*, *algorithms*, *functions* are hard to understand for beginners. I also made note that teachers from previous generations need a form of basic introduction in electronics and programming. One participant wanted to include possibilities to implement 3D printing in these projects. Two participants emphasized that digital tools should be a supplementary aspect of the subject. This again can be rooted back to the traditional values of art educators. I also recognize that the threshold to use digital tools relies heavily on the level of digital experience of the educator. This indicates that my solution must cater to a system based on progression, starting from those who are new to technology.

4.7 Final concept for prototype

After completing the project evaluation, I had decided to go through the data I had collected so far, to finalize a potential solution. Figure 4.18 summarizes my findings leading up to the final prototype. The underlying theme resulting from preliminary research is that the teachers' transition to implementing technology must be addressed. The method of how we introduce a new culture to an already established field is the main challenge. I agree with the teacher perspective that technology should not replace traditional values, but rather function as part of it. Therefore, my final prototype will operate as a platform to introduce digital fabrication, with the aim of demonstrating the art education that technology can enhance their practice.

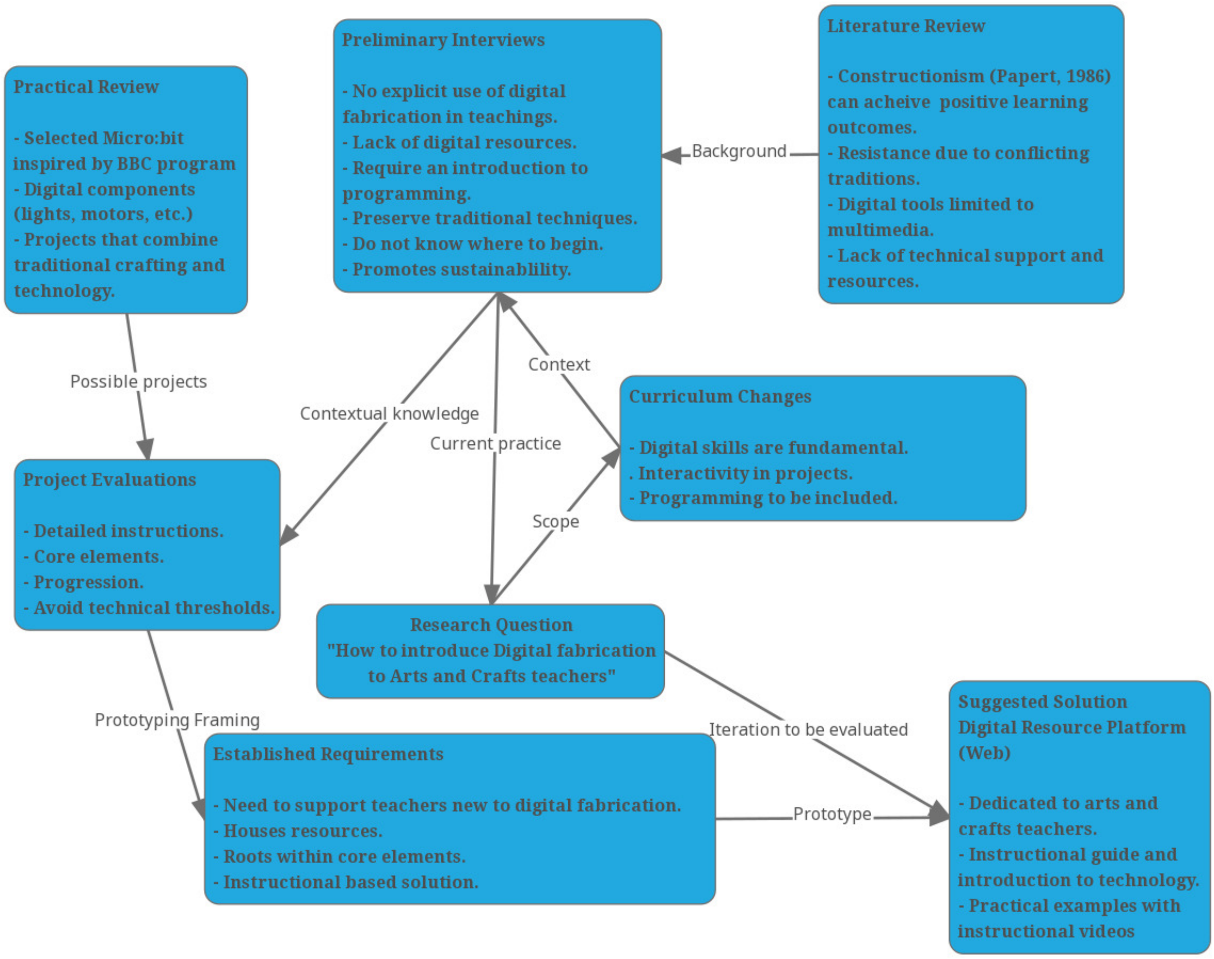

Figure 4.18: Mindmap summarizing the final framing of the prototype.

4.8 Designing the Digital Resource Platform

I began my design by sorting the content of the platform on paper as shown in Figure 4.19. Since I have already used Micro:bit through my research, my platform will be developed around it.

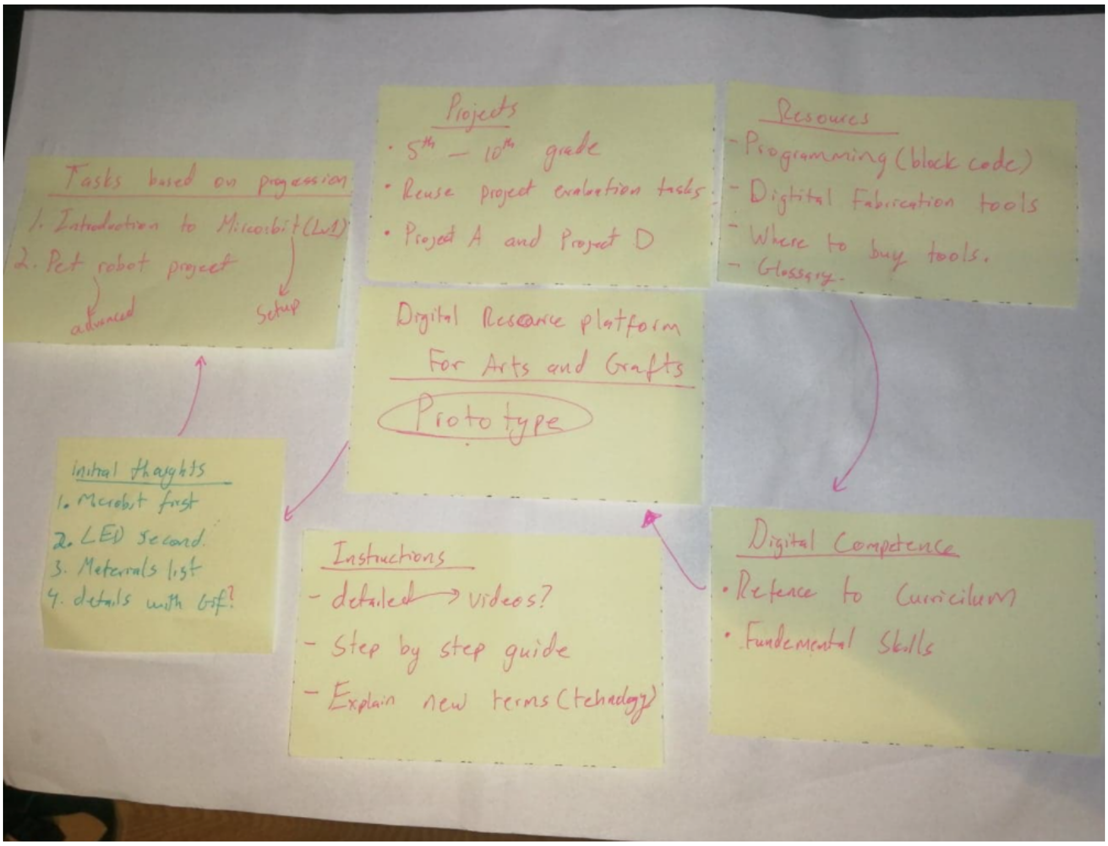

Figure 4.19: Brainstorming the contents of the prototype

The findings from the project evaluation suggest that the platform should be inclusive for different generations of teachers and start at a low level, assuming that a potential user has little experience with programming. The solution should also fill the gap of technical help with the use of detailed manuals. Overall, the platform will contain the following :

- A page that will introduce the microcontroller. Preferably the main page. This page will contain a simplified explanation on the specifications of the Micro:bit. In addition, the same page will refer to the changes in the curriculum, since it is yet to be implemented.

- Two projects that will function as examples, sorted on the merit of progression. The first project will help the user program their first block of code through the development program. The user will then go to the next project, which is slightly advanced and is based on the pet robot from the project evaluation (Section 4.6.2). It is important that these tasks are explained clearly.
- For users that are new to programming, the platform will include images of the code needed to complete the project.
- External resources that can support digital fabrication in arts education. This can come in the form of alternative microcontrollers, inspiration for future projects, support for programming, and a suggested guide on how to have a lecture using digital tools in arts and crafts.

4.8.1 Sketching the layout for the platform

Before developing the platform, I started to sketch the layout. I wanted to present the information in a pedagogic style. Figure 4.20 illustrates the main page of the platform. It is in this page the Micro:bit is first introduced, with a picture of the unit, along with simplified descriptions of the specifications. This is followed by two tasks that operate as introductory exercises, aiming to familiarize teachers with the technology. A list of supplementary resources to support digital fabrication in arts and crafts are at the bottom of the page. In addition, a summary of the relevant learning outcomes from the curriculum are also presented.

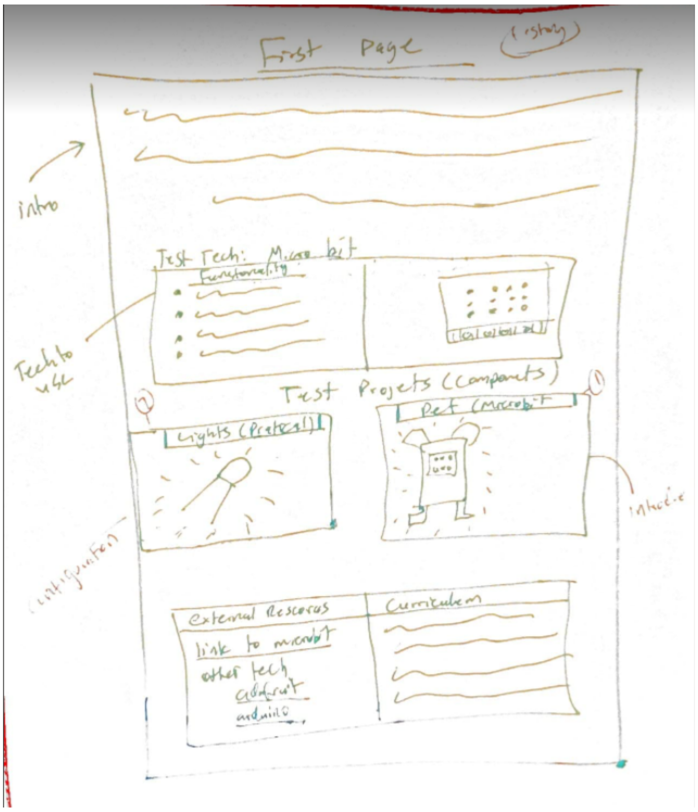

Figure 4.20: A sketch of the home page for the platform.

The second page that I had sketched as shown in Figure 4.21 focuses on the tasks that will introduce art educators to computing and fabrication. Based on the feedback from the data collected in this thesis, the page will start by explaining the objective of the task, as well as the learning outcomes that are covered. After the teacher has completed the task, a presentation of applications for arts and crafts topics are shown. Optionally, teachers can also submit contributions for other projects that can be performed using the same concept, in an attempt to give ownership to the practitioners.

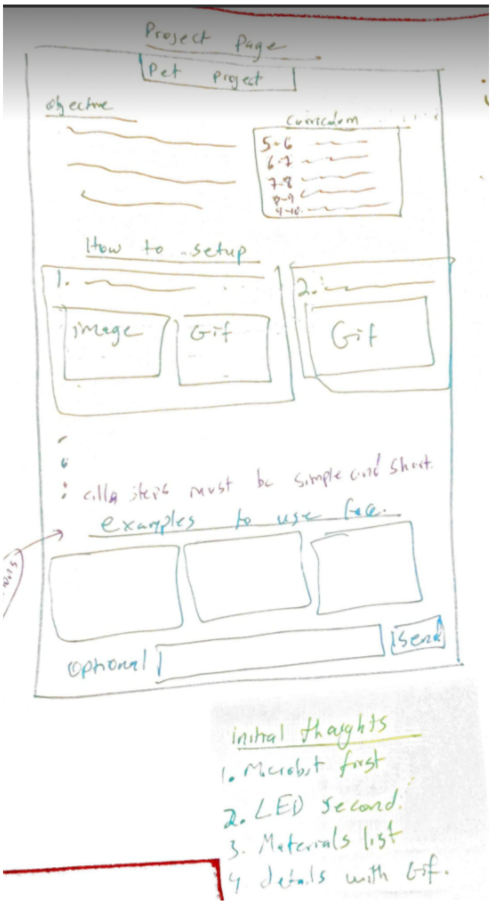

Figure 4.21: Task Page

4.8.2 Using Graphics Interchange Format to support usability

When it came to the manual for both tasks, I was inspired by a study on animation operating as an instructional manual (Jia, 2016). To shortly summarize, the results from that study showed that animated instructional manuals can support learnability. This is supported by similar studies, adding that animations that convey explicit information are effective in education and human-computer interaction. As the teachers will be joining complex components together, I argue that it can be beneficial to supplement the tasks with animated instructions using Graphics Interchange Formats(GIFS). This design choice can aid teachers to comprehend the usability of electrical components.

Furthermore, these graphical illustrations can create a scenario that can make the user feel as if someone is doing the task with them.

4.9 Creating the prototype

This section describes the final stages of the design step from Section 3.1.1. The final prototype is based on my interpretation of the findings from the preliminary interviews, practical review, and feedback from the project evaluation.

4.9.1 Technology Choices

I present the tools I have used to create my prototype. I begin by describing the technology choices in developing the platform. Furthermore, I present the software used to create the animation for the instructions that will supplement the description of the more complicated steps. As I have mentioned earlier, I use Micro:bit as the control board for both tasks. I recognize that the choice of each component of the prototype will have an impact on the results. This is however expected in the field of *research through design* (Zimmerman and Forlizzi, 2014). The prototype will function as an attempt to explore the usability of digital tools in the context of arts and crafts.

Google Sites for creating website

I have used Google Sites[15] to create the web platform. The selection of this solution was based on a time limit during the development of the prototype. Google Sites is a free web page development tool that allows users to create websites at a fast rate. One advantage of this solution is its integration possibilities with other Google services, such as Google Slides and Youtube. This feature allowed me to embed the development platform for

[15] Google Sites `https://sites.google.com/`

Micro:bit so that the teachers can see the code for their tasks. These simplistic features, along with the options for editing as seen in Figure 4.22 allowed me to focus on the content of the platform.

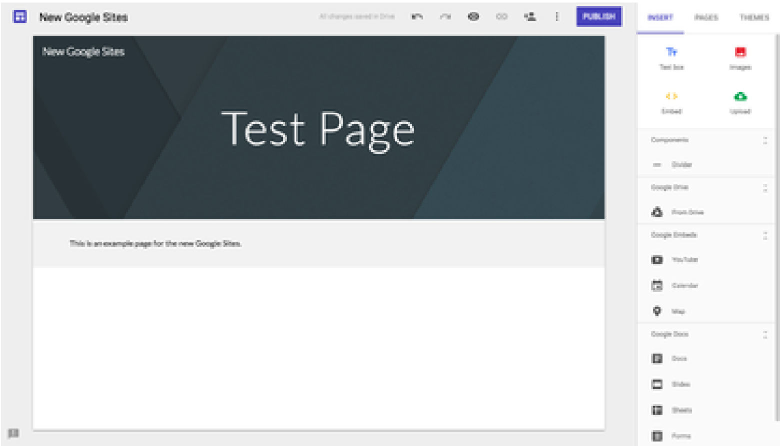

Figure 4.22: Sample of a screenshot of the editing mode in Google Sites

Recording tool for animated instructions

I used ScreenToGif[16] to record the illustrations of each step where I deemed necessary and create animations. This software allows me to record the screen, webcamera, or both to create short GIF animations. When using the screen recorder functionality, I focused primarily on the steps that involved programming on the Micro:bit development platform as shown in Figure 4.23. I used the webcamera feature to illustrate how to join different electrical components together, as well as how to connect the Micro:bit to the computer for new users.

[16] About ScreenToGif: `https://www.screentogif.com/`

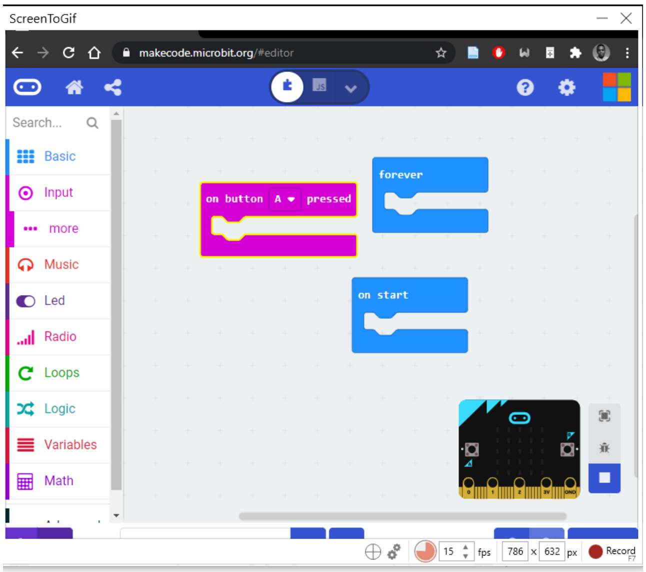

Figure 4.23: Interface of recording animations using ScreenToGif

Chapter 5

Digital Resource Platform

This Chapter presents the implementation of the prototype[1], based on the design from the previous chapter. The web application consists of four pages which will be described. Figure 5.1 illustrates the top of the home page, introducing users to the platform. Section 5.1 pertains to the home page, while Section 5.2 outlines the two tasks that will introduce teachers to Micro:bit. Section 5.3 directs teachers to supportive resources from which they can expand to other possible applications for their practice. I implemented animations on the steps that required programming, in addition to the technical steps where the user will join the components together with the Micro:bit. The platform is most useful in the condition that the user receives a dedicated set of components with the exclusive digital tools needed to complete both tasks.

[1] Digital Platform: `https://sites.google.com/view/mastersfahadhiof/home`

Figure 5.1: Screenshot of digital platform with a short introduction to potential users.

5.1 Home Page

Figure 5.2 illustrates an short introduction about Micro:bit, describing the technology. This is to get the user to be familiar with the tool they will be using in the upcoming tasks. In cases where the user would be interested in learning more about Micro:bit, they can be directed to an external webpage in Norwegian. The home page also presents examples of crafting projects with Micro:bit in a gallery format.

Figure 5.2: Introducing the Micro:bit on the home page of the platform.

Before the user begins with the first task, the platform provides instructions on how to connect their unit to the computer. This is followed by a brief description of the programming platform they will use to program their Micro:bit. The following sections will present the two tasks in more detail.

5.2 Task Pages

Figure 5.3: Screenshot of the tasks the teachers will evaluate.

In this section, I describe how the platform presents the tasks that the teachers will evaluate. Figure 5.3 illustrates the presentation of the tasks on the platform. Based on the research I have conducted in this thesis, the tasks I have chosen will cover the following learning outcomes in the curriculum for students between the 5th and 10th grade derived from Section 2.2.3.

5.2.1 First Task: Create A Picture With Micro:bit

This task functions as a general introduction to programming, aimed directly towards teachers that are new to the field. Here, the platform explains that they will learn how to use block-based programming. It is important that the platform clarifies the technical terms that the user will be introduced to. Using the software for creating animations, in addition to the description of each step, the platform guides the user to create their first block of code.

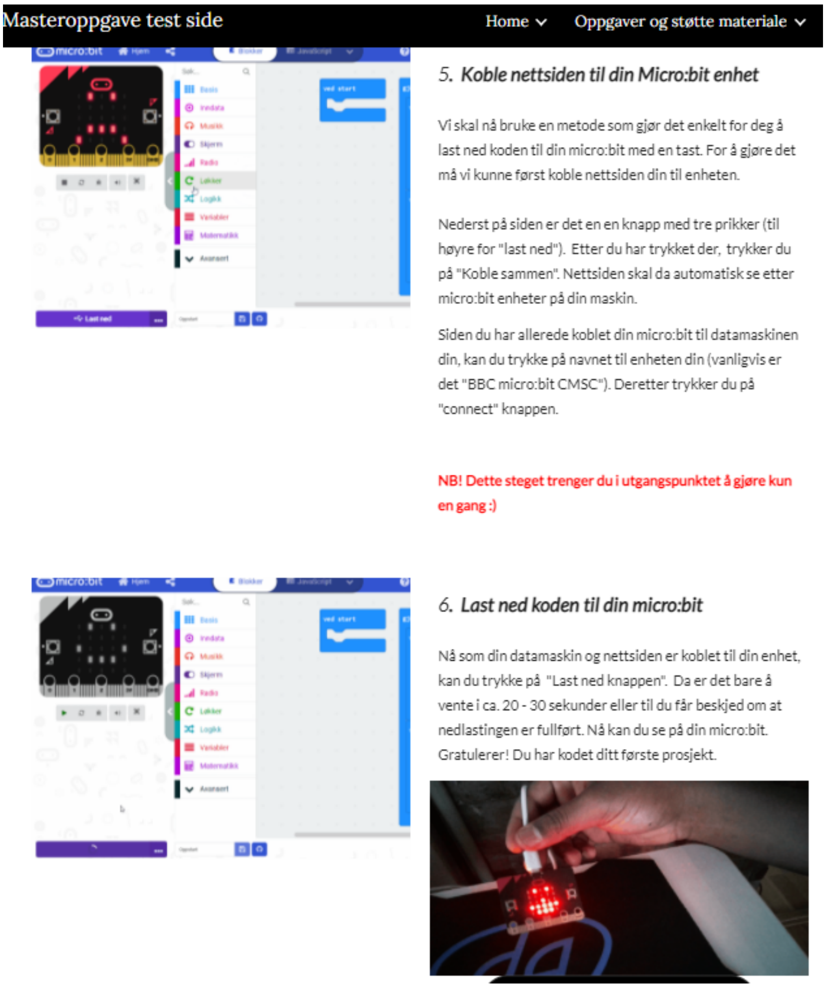

Figure 5.4: Screenshot of the last step in the first task of the platform.

They will create a smiley face on the Micro:bit that frowns when you shake it. After completing 5 steps, Figure 5.4 shows the user the final form of the task. After they have completed their first task, the platform shows a series of similar applications as shown in Figure 5.5.

Figure 5.5: Screenshot of the first task in the platform. Slideshow of possible applications within arts and crafts when using the Micro:bit as a face.

5.2.2 Second Task: Creating A Pet Using Micro:bit

This second task is relatively more comprehensive than the previous one. Nonetheless, it builds upon the knowledge obtained in the first task. Furthermore, the task involves an explicit combination of crafting techniques, motor installation, and programming. The aim of the task is to create a pet that can respond to a simple interaction. I created a rabbit that shakes its tail and changes its facial expression if it is shaken. At the beginning of the task, I list the equipment needed, including a motor, a set of dedicated cables, and electronic clamps as shown in Figure 5.6. I explain further that the user should plan what kind of model they want to create as a housing for the equipment.

Figure 5.6: Screenshot of the second task, with the list of equipment and prerequisites.

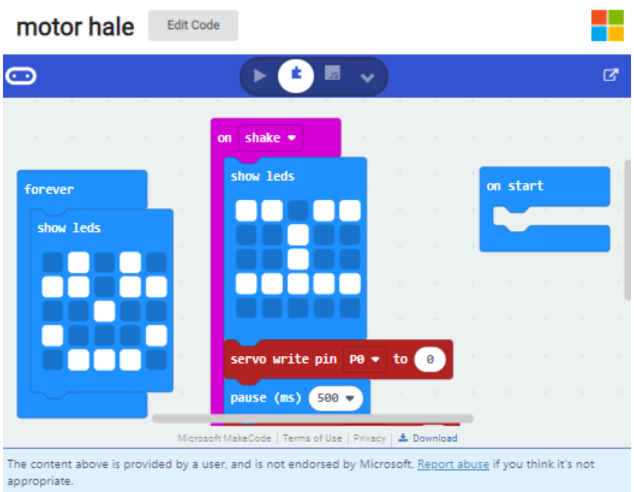

Figure 5.7: Screenshot of the final code for the second task, embedded from the development application for Micro:bit

As they progress through the task, they create the code needed to (1) initiate the LEDS in the Micro:bit, (2)insert a few blocks to manipulate the motor, and finally (3) make the Micro:bit react to an interaction. The user will then see how I have programmed the rabbit's tail using the embedding feature of Google Site as shown in Figure 5.7. I use this specific feature because the user would be able to see where each block of code came from.

Figure 5.8 illustrates how the platform guides the user when joining components together. With the dedicated set of cables, I made sure they were colored so that the user can ensure that the colors match, avoiding user errors. I refer to the numbers on the Micro:bit as well for further guidance.

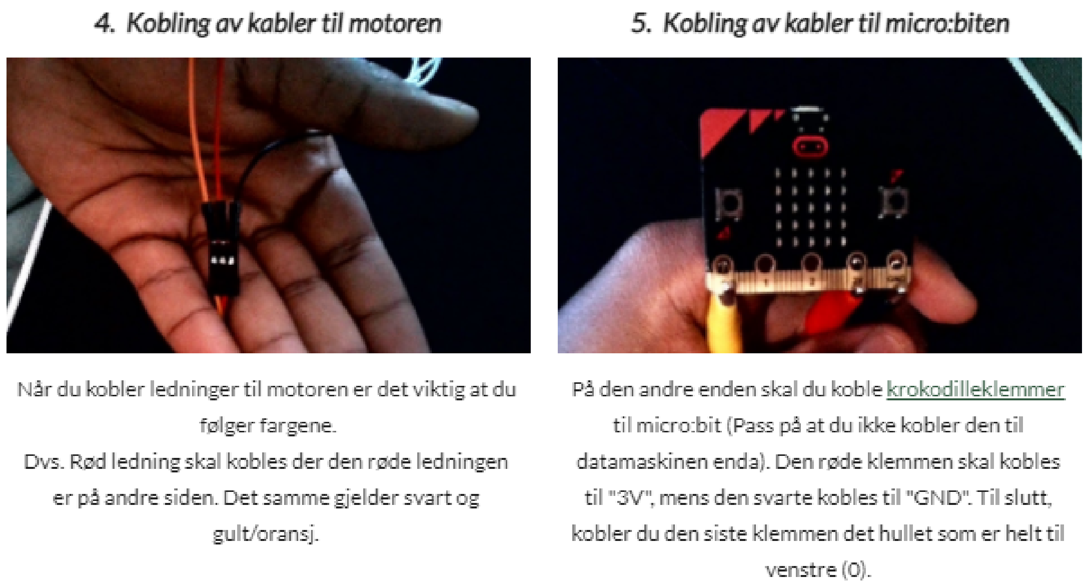

Figure 5.8: Screenshot of the platform explaining how to join components with animations.

5.3 Resource Page

This page is for those that are interested in exploring digital fabrication further, as well as teachers looking for extra support in the fundamentals that were covered in both tasks. Figure 5.9 illustrates how the page presents these supplementary resources. It consists of a list of other projects from other institutions that they can look into. Other technologies, such as Arduino, Makey Makey, Little Bits and Circuit Playground express are listed.

Figure 5.9: Screenshot of the resource page from the platform.

Furthermore, I also present mechanical movements by PaperMech, to show teachers that there are multiple ways to create movements that can benefit specific art projects. I added a guide to how one can work with digital fabrication projects in the classroom to provide the user with a structure they can start with using the technology they have been introduced to.

Chapter 6

Results

This chapter presents the findings resulting from the evaluation of the final prototype outlined in Section 3.5.6. The evaluation was performed with four teachers that practiced arts education. Using qualitative analysis, I will summarize the findings from the four participants that have taken part in this evaluation. As mentioned in Section 3.5.6, I created a list of questions that each participant has answered to provide a structure for data analysis. I intend to present my findings based on the contents of the digital platform. The chapter begins with the participants evaluation of the home page, followed by the two tasks provided in the platform, in addition to the findings from the resource page. Figure xx summarizes the findings in relation to each page of the platform. Finally, I present findings pertaining to the relevance of the prototype in arts education.

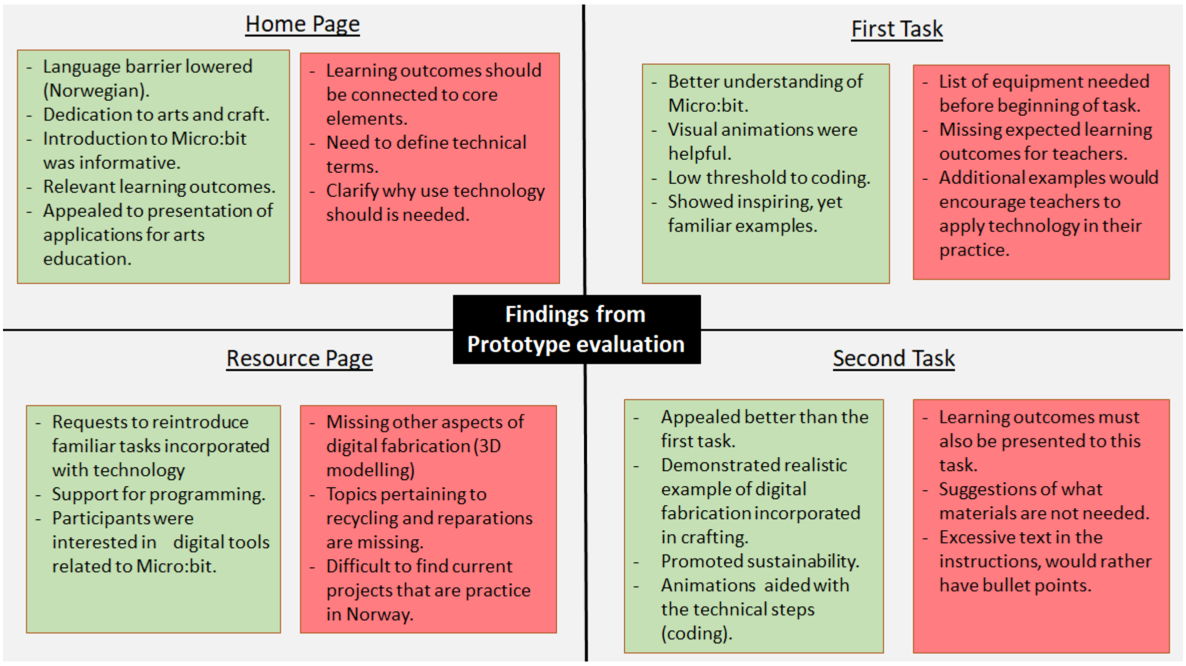

Figure 6.1: Summary of the findings extracted from the evaluation of the prototype.

6.1 Home Page

This section covers findings pertaining to how the technology was introduced to potential users. At first glance, all participants found the platform being dedicated to arts education appealing. With the platform's language being in Norwegian, it was evident that it helped the participants in the learning of digital fabrication tools. Two participants expressed that their previous attempts at trying similar projects were time consuming due to the language of the manufacturer. All participants found the introduction of the Micro:bit to be informative and engaging. Furthermore, the general impression of the platform from the participants was that it was easy to comprehend how the Micro:bit functions with its specifications. When it came to the presentation of possible applications of using the Micro:bit in arts and crafts, the participants found the examples on the home page to be useful. This also correlated well with the outline of the relevant learning outcomes extracted from the curriculum. One participant expressed that the learning outcomes should be supplemented with the core elements of arts and crafts. The participant added *"There should be arguments within the platform that can give the teachers feelings of encouragement as well."*. This implied that the benefits of implementing technology in arts education should be highlighted. Furthermore, the participant explained that although some of the learning outcomes could be interpreted differently, the home page can provide teachers with possibilities to implement similar technologies in their teachings. Another weakness that was made aware in this evaluation was the lack of explicit introduction to technical terms such as *programming* and *code*. These are terms that most computer users are still familiarizing with. One participant emphasized the importance of explaining such terms, as this is being taught to young students. It was suggested that the platform should contain a glossary with simplified explanations in the home page to solve this.

6.2 First Task

Findings from the evaluation showed that the introductory nature of the first task provided the participants with a better understanding of how to use the Micro:bit in practice. One participant used the Micro:bit and followed the instructions for the first task, reporting that the steps, along with the visual illustrations were informative. The animation of the coding steps seemed to fulfill its instructional nature as explained by a participant: *" The short visual illustrations makes it easier for me to connect to the Micro:bit"*. The same response was made by two participants when asked about their understanding of the code needed to create a picture on the device. As this task was meant to be an introduction to using the Micro:bit, the findings show that the participants recognized the value of the applications of using the Micro:bit as they referred to the examples at the end of the task page. Findings also show that these possible applications for using Micro:bit were useful for finding inspiration for future projects. One participant asked if it was possible to expand the task to use LED lights on a larger board to use for collaborative group work. According to two participants, the highlighted gallery at the end of the first task showed that those projects were not necessarily new, but rather enhanced with the use of digital tools, which can appeal to traditional teachers. Findings from the first task indicate that the platform lacked an explanation of the potential learning outcomes from a teacher's perspective. In the evaluation, a participant suggested that teachers should know the expected outcome after completing the task, with reference to the curriculum, otherwise they would lose interest. It was also noted that there was a need for a brief explanation of the equipment needed at the beginning of the task. Despite their implicit understanding that only the Micro:bit was needed in the first task, the findings revealed that it was important to take it into consideration in a scenario there were teachers with lower digital competence. Two participants preferred to have the instructions in the form of bullet points.

6.3 Second Task

Findings from the second task show that it appealed better to the teachers compared to the first one. Three participants expressed its value for combining a crafting project with fundamental programming. This notion was explicit by one participant who said: *" ..this task is can help older teachers understand that it did not replace crafting, it relies on it for the pet to be complete"*. This finding indicates that this task can address traditional art educators. The participants expressed that the knowledge they had obtained from the first step encouraged them to explore this task. Similar to the first task, the participants found it easier to understand how to complete the task using animations on the technical steps. This indicated that the animations were useful in the context of instructional information. One participant added that it was useful to have a color code reference in the assembly steps when connecting the motor to the Micro:bit. This was also the case with the other participants, suggesting that the short animation of the code and presentation of the assembly lowered the threshold to work with the Micro:bit. The lack of learning outcomes for the teacher was also missing in this project. In addition, the broad nature of the project raised questions from one participant who wanted to know what materials should be avoided. Findings from two participants reveal that the text supplementing the instructions is perceived to be in excess and should be divided into concrete step descriptions. This was expressed by one participant when asked about the presentation of the tasks: *"..the images help with how to perform the tasks in each step. There should be less text."*. The participant added that the illustrations provided sufficient information to complete the task. This conflicted with another participant as they praised the information provided by the animations.

6.4 Resource Page

When it came to the resource page, the findings showed that the participants were interested in references to other technologies that are similar to Micro:bit. When asked about the number of tasks, three participants were clear that there was no need to expand on them at this time as they were sufficient to be introductory tasks. However, the findings also reveal the participants interest in other tasks that can cover other aspects of arts education. One participant suggested that the platform could collect traditional tasks and publish their enhanced versions with digital tools: *"I think it can help other teachers if there were other examples also..if it is possible, maybe the teachers can submit their projects and receive instructions on how to use digital tools.*. Furthermore, another participant added other applications that require reintroduction: *"is it possible to add other aspects of arts and crafts such as pattern based art or 3D printing?"*. This finding also indicated that there is a need to add other aspects of digital fabrication, such as additive fabrication. Another topic within arts education in Norway that was not covered according to one participant was reparations. Implying that there should be room to look at projects that focused on recycling old items using digital tools. Another suggestion extracted from the evaluation is the application of LEDs to create glowing shoes, to be more visible at night.

6.5 Relevance of the platform in Arts education

All participants were interested in using the suggested platform to implement digital fabrication in their practice. In the light of the changes made by the Ministry of Education, the general impression from the participants was that the platform can support the implementation of fabrication tools in arts education. One participant disputed the notion of using learning outcomes as the main argument to apply technology in arts. This is because the learning outcomes are only detailed points of the core elements of the subject, which are outlined in Chapter 2. When it came to the question of how they would use the platform, three participants preferred experimenting with the Micro:bit alone at first, before practicing it. This is because they wanted to make sure that they were confident of their competence in case they were to be asked questions during class. The same participants also responded positively to the way the platform provided each task with the final code to avoid frustration at the early stages of learning. In the case of one participant, they would try the platform in the classroom without any prior preparation. In this way, they class would also be challenged to work independently on the project, as they mentioned that it is more likely that the students would understand the technology better than them.

Chapter 7

Discussion

In this chapter, I discuss my research questions in light of the findings presented from the results of the evaluation of the prototype in Chapter 6. I will also use the findings extracted from the literature review conducted in Chapter 2, and the findings from the preliminary interviews from Chapter 3. To reiterate, the research questions are as follows:

RQ 1: How can digital fabrication be introduced in the subject of arts and crafts ?

This is divided into two subresearch questions:

RQ 1.1: *What are the demands in the new curriculum and how do they affect the current use of digital tools in the subject of "Arts and Crafts"?* I address this subresearch question in Section 7.1 using the findings from the preliminary interviews and theoretical background generated from the literature review.

RQ 1.2: *How can the introduction of digital fabrication be facilitated in the subject of "Arts and Crafts"?* I answer this subresearch question in Section 7.2, with a discussion on how the prototype has addressed the needs of the teachers, supplemented with suggestions on the changes needed based on the results from Chapter 6.

In the following sections, I outline the conditions necessary for introducing digital fabrication in the subject of arts and crafts. This begins with a discussion on how changes in the curriculum affect the current practices in today's K-12 programs. This addresses the first subresearch question. In addition, I discuss how the prototype can support art educators in their use of digital tools. Subsequently, I discuss the second subresearch question, using the results from data collection and theoretical background. Furthermore, I shed light on the core methodology and reflect on the design choices I made throughout this project. The limitations of this thesis will also be covered in this chapter. Finally, I shed light on how the ongoing restrictions as a result of the COVID-19 pandemic have influenced my initial intentions and research.

7.1 Implications of the changes in the Norwegian Curriculum

This section answers the first subresearch question with an analysis of how the changes in the curriculum affect current practices in Norwegian arts education. Throughout the years, policy makers have pushed the education sector to adapt to the changing world around them. This is due to a trend instigated by business groups and international organizations such as OECD, focusing actively on STEM subjects (Blikstein, 2018). Keywords such as *"innovation"* and *"problem solving"* are typically what international organizations and governments look for when applying changes in their educational platforms. Previous literature has praised the use of digital fabrication in education, with rewards such as democratization and higher problem solving skills (Blikstein, 2018; Eriksson et al., 2019; Montero, 2018). This has also been the case in Norwegian education where they explicitly imply that changes in arts education will create room for interactive products, innovation, and problem solving[1]. However, with a change that is nationwide, one must be able to acknowledge possible complications. Based on findings from the literature review and preliminary interviews, I argue that the lack of communication

[1]Announcement from Directory of education: `https://www.udir.no/laring-og-trivsel/lareplanverket/fagspesifikk-stotte/nytt-i-fagene/hva-er-nytt-i-kunst-og-handverk/`

between the education sector and policy makers has created barriers. These barriers have proven to have a significant impact on how art education perceives the use of digital tools in Norway today (Lyngsnes and Rismark, 2017).

Findings from the literature review emphasize the importance of the teacher's role when working with digital fabrication in the classroom (Dougherty, 2012). In order for students to see the value of what is shared, the teacher should be updated on current advancements in the relevant field. Based on findings from the preliminary interviews, teachers have not been provided with a sustainable transition considering the changes made by policy makers. This was acknowledged by Ottestad et al. (2014b), highlighting this is as a challenge on a national level. During the course of this project, I have recognized that a teacher faces multiple challenges in practicing art education, which has resulted in discrepancies between the new curriculum and current practice. One barrier that has been identified by previous work is the traditionalists resistance to adopting technology in arts education. Findings from the preliminary interviews indicate that many teachers do not see the value of adding more technology to the classroom due to time constraints. Traditionalists have also challenged the notion that technology does not promote originality as stated by Ettinger (1988). One must also take into consideration the limited resources provided to the education sector as a significant limitation for implementing digital fabrication in arts education (Schad and Jones, 2020). Findings from the preliminary interviews highlights that the participants lack supportive mechanisms to achieve these goals. Blikstein and Krannich (2013) outlined this limitation, along with the lack of digital competence as some of the issues in implementing digital fabrication in education. Although there seems to be multiple platforms that can facilitate technology in STEM subjects, to the extent of my knowledge the same does not apply to arts and crafts. I argue that the activities in art education that are practiced today are still prioritized as a result. Despite the ongoing growth of fabrication labs(Song, 2020) and increasing access to dedicated facilities, the subject of arts and crafts still holds on to its traditional roots of material understanding, perspective analogy and visual arts (Sømoe, 2013). The study done Ettinger (1988) shows similar pedagogic issues. Furthermore, learning new technical skills can also be characterized as barriers according to Song (2020). The author explains further that the lack of technical support from professionals increases the art educators' threshold to use digital tools (Song, 2020; Ettinger, 1988). Findings from the preliminary interviews demonstrates the teachers call for professional support to use digital tools. This notion appeals to the reasoning behind the teachers being directed towards multimedia options, and using computers for information retrieval as I had discovered in the preliminary interviews. This was also consistent across previous literature (Olsen, 2014; Imsen, 2020).

Hypothetically, if teachers were provided with the equipment needed to practice computing in the classroom, there would still be a conflicting threshold to use them as intended. Findings from the preliminary interviews suggest that the lack of supporting mechanisms makes it difficult to approach a new field. In addition, based on the findings from the project evaluation, art educators require a starting point to implement digital tools in arts and crafts. According to the analysis on the use of ICT tools in arts and crafts by Vavik et al. (2010) art educators' assessment of digital tools, these factors naturally decrease the pace of applying technology in arts and crafts, opposing the demands made by policy makers.

Another factor that may be overlooked is the curriculum itself. As mentioned in Chapter 2, depending on the teachers' perception or background, the learning outcomes in the curriculum can be interpreted differently. This interpretation could be heavily influenced by current attitudes towards technology in the context of arts education (Imsen, 2020). I attempt to challenge this, as one cannot overlook the core elements of the subject, which operates on a higher level than the learning outcomes. This was also supported by the findings in the evaluation of the prototype. Furthermore, the core elements mentioned in Section 2.2.2 are reflected in the learning outcomes, and thus must be followed, regardless of interpretation. However, based on my findings from the interviews, teachers practicing arts and crafts still require a medium to satisfy the core elements. With this in mind, it is important to reflect on the curriculum itself as Song (2020) mentioned, as it must represent the availability of equipment and digital competencies in the field in question. I argue that it is evident that teachers need to be facilitated with digital tools to comply with the requirements set by policy makers.

7.2 Using the Digital Platform to Support Teachers

This section addresses how digital fabrication can be facilitated in arts education using a prototype. This subsequently answers the second subresearch question. Figure **??** provides an overview of how the prototype has attempted to facilitate the teachers' implementation of digital fabrication in arts education. Based on previous work, art education in Norway are met with barriers that limit their implementation of digital fabrication. These barriers have emerged more clearly with new changes to the curriculum from policy makers. Current practices in arts conserve traditional methods of crafting due to a lack of technical support. The digital platform was designed to facilitate art education by adopting familiar projects from current practices and incorporating them with technology.

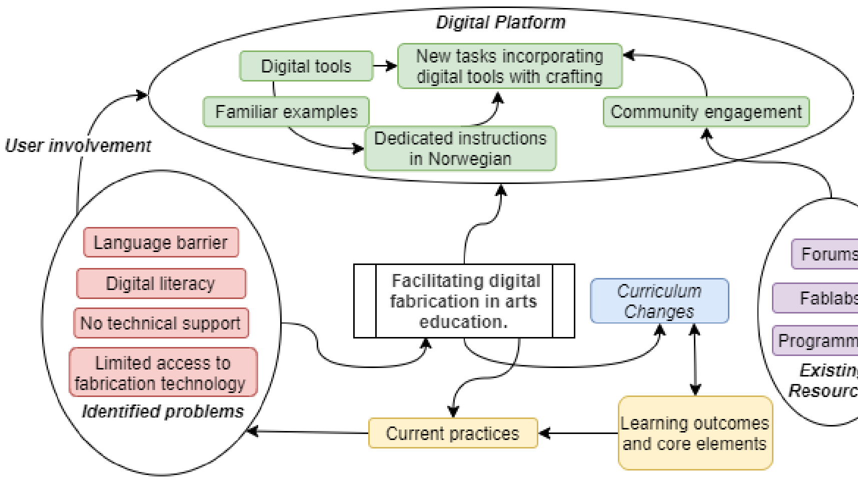

Figure 7.1: Mindmap illustrating how the work from this thesis attempts to introduce art teachers to digital fabrication.

Considering the established requirements outlined in Chapter 3, the digital platform was able to address some of the problems identified in Chapter 2. Firstly, there was the issue of understanding the fabrication tools and applying them. The home page of the platform provided teachers a description of the technology in their native language, aiding their understanding of the Micro:bit. The platform aided the participants to recognize the potential of implementing digital fabrication in their work, increasing their confidence in their digital competence. This result validates the findings from Song (2020), showing that art teachers can be more receptive to the potential of fabrication technology. Further understanding of how to use the digital tool was reinforced based on the participants' responses to the first task from Section 5.2.1. Findings from the prototype evaluation suggest that the platform's dedication to arts and crafts were appealing to the teachers. When it came to the second task from Section 5.2.2, the animations used on the steps that pertained to coding and component assembly were useful for the participants. This suggests that art educators' threshold for technical understanding was lower with the use of animated illustrations, making it easier to complete the tasks. Arguably, this way of providing instructional content to users as suggested by Jia (2016) is a valuable area worth exploring further.

The positive responses to the tasks from the platform could be due to the teachers' familiarity with the tasks, as they have been derived from current practices. Results from the evaluation suggest that the optimal way to support art educators is to provide them with projects that incorporate digital tools in the current activities that are practiced today. Reintroducing a familiar project with the enhancements that the technology provides seemed to have a higher acceptance rate from the participants based on the results from the prototype and project evaluations. This approach makes the claim that the digital platform can to some degree close the digital competency gap that teachers have with fabrication tools. According to Song (2020), incorporating digital tools in art education can be beneficial in cross-disciplinary topics, which was also noted in the project evaluations. The participants' response to the third project from Section

4.6.3 indicates that it could have been done as part of promoting sustainable energy in other STEM subjects. The National curriculum mentions cross-disciplinary topics like environmental preservation, sustainability, and recycling, implying that the project could be used in that context. Based on this finding, I argue that the platform can supplement art educators with tasks that can cover such topics in detail. Furthermore, participants from the prototype evaluation wanted the platform to extend to students as well, which was also interesting, as three participants would rather use the platform for themselves prior to using it in the classroom. This could indicate the transition towards ownership and empowerment of the students' digital citizenship. On the other hand, this would raise questions on the role a teacher should have when operating with digital tools (Imsen, 2020). Vavik et al. (2010) raised concern on how the use of technology can impact the culture in the classroom. As Krumsvik (2006) implied, the use of digital tools depends on the teacher applying it, and under the right circumstances, it can upheave education.

According to the results from the prototype evaluation, the participants wanted the platform to be supplemented with other activities that are practiced in arts education today. These activities would be then translated to tasks that were incorporated with technology. Furthermore, other aspects of digital fabrication are missing, such as additive manufacturing (3D printing). One participant in the prototype evaluation raised this issue as well. This stems from the concept that crafting is not only about creating, but also about problem solving by learning how to repair items with digital tools. Findings from the prototype evaluation also show that there should be other modular-based tasks for each type of task in arts education. There should be room to include textiles, pattern drawing, and other topics within arts and crafts. I found it difficult to extract currently practiced activities from the teachers in the preliminary interviews, which made it challenging to recreate them with the integration of technology. In addition, the work required to gather all projects from teachers and transforming them would be excessive for one entity to tackle. The platform should rather aim to inspire teachers to create their own projects with the technical help the instructions provide in the introductory tasks. Furthermore, I investigated similar solutions to the platform in the Norwegian education sector. To the extent of my knowledge and perception from the practical review in Section 4.4.3, there is a lack of digital fabrication-based projects that are dedicated to Norwegian schools. At the later stages of the research however, I discovered that there was a Norwegian based programming platform for children, *Lær Kidsa Koding*[2]. Similar to the prototype, they provide some tasks with varying levels of programming, but only one task that focused on the explicit use of digital fabrication , covered in Section 4.4.3. The platform can address these issues if it were to be restructured to a user-based cocreative platform. By allowing teachers around the country to engage with the platform, we can expand the possible tasks in it and facilitate potential users with a variety of options. This creates a need for a collaborative approach, as the subject is broad and there are different variations that are covered within handcrafting. As there are different types of art educators in the field, the platform can invite teachers and current educational resources to submit projects that are relevant for arts and crafts. The implications of this approach can help establish a community that shares the pedagogic expertise within the subject. It would be able to reinforce the teachers' ownership of their field while also fulfilling the demands made by policy makers. Work resulting from community engagement in this context can empower the democratization of fabrication, and enhance education (Blikstein, 2018). The acceptance of these tasks by traditional teachers could also be more likely if it were introduced by workers in the same profession.

7.3 Research Through Design as a Methodology for this Thesis

In this section, I discuss the core methodology and reflect on the selection, as well as the implementation of the methods. Furthermore, I look into the approaches I have taken in

[2] Lær Kidsa Koding: `https://www.kidsakoder.no/`

the context of prototyping, based on the research triangle adopted from Fallman (2008) as explained in Section 3.3.1.

7.3.1 Implementing Research Through Design in the Project

At the beginning of this project, I wanted to use concepts that could probe the education sector, using my experiences from our local Makerspace. I was also new to the field of pedagogy and was interested in understanding the underlying issues within arts education which was resistant to technology. In addition, I needed to work on a framework that could provide a systematic structure for my project work when deploying design activities to explore the problem space. This led to my approach to research through design as the core methodology. As explained in Chapter 3, this approach was suitable as the nature of my work was exploratory. On the topic of conducting research with structure, I adopted the five-step plan for applying RtD by Zimmerman and Forlizzi (Olsen, 2014, pp.184-186). I felt that this framework has helped me spilt my research into seperate, yet concrete phases, making the end goal clearer after completing each step. Most importantly, this framework allowed me to adapt quickly to the drastic changes caused by COVID-19, which I will cover in Section 7.5. I had also framed the nature of my work by adopting the field approach to RtD from Koskinen et al. (2011). All design activities have been based on gaining context, and developing a realistic solution. Due to this selection, I could see the value in reviewing existing toolkits as shown in Section 4.4.2 as it inspired me to create the projects that were evaluated by teachers in Section 3.5.5. I felt that it was beneficial to use the field approach as it allowed me to use existing technology to understand how it mediates the communication between the demands set by policy makers and the actual practice in arts education. This is an important narrative that Koskinen et al. pointed out: *"Field researchers believe that to study humans and their use of design they need to understand their system of meanings"* (Koskinen et al., 2011, p. 69). I have used the very tools that primary users were resistant to, and extracted real data that is reflected within the theoretical background I studied, which has provided value for further research. I also recognize that applying RtD entails a process where a researcher does their work in multiple iterations. However, due to the limited time for the project, I focused on investigating the underlying issues that can improve the next iteration. When first working with RtD, it took me a while to comprehend that there was little literature on how to deploy it, compared to other methodologies (Zimmerman et al., 2010). Despite that, I documented my perception on each method in Chapter 4.

7.4 Reflections on the design activities

I spent most of my work on the second step (design)(Zimmerman and Forlizzi, 2014), allowing me to gather useful knowledge before ending up with the final prototype. I will now discuss the design activities in relation to the research triangle adopted from Fallman (2008). I first conducted a literature review and explored the Norwegian education system focusing on arts education, satisfying the prequisites for applying RtD (Zimmerman and Forlizzi, 2014). The findings from that stage provided me with theoretical knowledge in the area of design studies. If given the chance, I would have used more time to explore the context of arts education in more detail. It would also be beneficial to investigate more concrete tasks to feed the prototype, accommodating to the needs of the teachers based on experience. I also regret not investigating the function of teacher education in the context of computing, as they lay the foundation to the teachers for upcoming generations as well.

I performed preliminary interviews with art educators, including them in the development process and generating conceptual knowledge. In addition, a practical review of the existing digital tools dedicated to education was performed. These two activities operated as the foundation for evaluating possible projects with teachers. The work that resulted from the project evaluation, in addition to the activity of prototyping roots in the area of design practice(Fallman, 2008). The evaluation of the digital platform was implemented on to the area of design exploration, the origin of the research. The use of the research triangle was useful for my work, as it illuminates the findings from each area and clarifies the requirements needed to (1) answer my research questions and (2) suggest a solution for art educators. Using this framework for prototyping(Fallman, 2008), along with the core methodology of RtD was helpful in completing the project. Each activity provided input to the next activity, which made it easier for me to frame towards the final prototype.

Using a user-centered approach as described in Section 3.5.7 helped me increase the validity of my findings towards the prototype. This is also supplemented by the characteristics of design research mentioned earlier by Koskinen et al. (2011). My reflection of using a user-centered approach is that it establishes an environment where we collaborate with one another. It was challenging to balance the level of involvement from potential users, as there was a barrier when it came to digital competence. However, I feel that I have maintained a sustainable level of collaboration with the teachers involved in this project by extracting conceptual knowledge from the preliminary interviews. By grasping their perception of digital tools and applying research through design, the final prototype presents practical and applicable results, which is valuable for future work.

7.5 Adjusting The Thesis To The Ongoing Pandemic

Unfortunately, this project has been challenging to complete due to the current circumstances we live in during an ongoing pandemic [3]. This section will first describe the intended plan of this project. This is followed by a series of challenges that led to me shifting towards alternative solutions to conduct the project.

[3] Viken undergoes pandemic guidelines https://www.regjeringen.no/no/aktuelt/innforer-strenge-regionale-tiltak-i-hele-viken/id2838828/

7.5.1 Original Plan

At the earlier stages of the project, I planned to create a tangible prototype that is dedicated to digital fabrication for arts education. The idea was to create a toolkit, combining microcontrollers and electrical components with crafting tools. The prototype was to be evaluated in an educational conference as part of an exercise for teachers. I had also planned to create a set that could be tested in higher education with preservice teachers. In addition, I was planning to conduct a session with potential users in brainstorming sessions. I also wanted to observe a couple of art classes in K-12 schools to collect data on the activities that were practiced. As early as of March 2021, the Norwegian government classified the entire county at the highest contingency level due to the rise in confirmed cases, causing the institution to shut down its doors to students and employees alike. This removed my only possibility to create a tangible prototype and its respective evaluation as intended. The design activities with participants were primarily conducted through distributed meeting systems (Zoom and Microsoft Teams).

The restrictions during the project have created barriers to conducting the intended activities, causing me to change my approach to a distributed solution. This has evidently led to a different prototype then what is planned. I will discuss the challenges concerning the education sector in the next section.

7.5.2 Strain on education sector

The restrictions forced schools to implement digitally based education. In the context of arts and crafts, this change entailed a minimum of physical interaction. Consequently, it was challenging to recruit participants for design activities. The same challenged applied to conducting them through distributed systems. This showed that even if I performed the intended activities, there would still be a challenge in applying the intended methods in an unusual situation.

Despite the challenges stated in this section, the project still contributes valuable research. Furthermore, the prototype in this form adapts to the current situation and can still support digital fabrication in arts education.

Chapter 8

Conclusion

In this thesis, I have explored the relationship between technology and arts education with a theoretical background. Furthermore, I have examined how the changes in the curriculum affect the current practice in the subject of arts and crafts in Norwegian K-12 programs using qualitative methods. Throughout the project, I applied Research through Design as my core methodology, adopting frameworks that structure the basis of my work. The activities that followed resulted in the creation of a prototype that introduces teachers to digital fabrication using a digital platform that functions as (1) an entry program for beginners, and (2) a supplement for teachers that need to fulfill the requirements set by policy makers. The prototype was the result of an iterative design process with a user-centered approach. With the implementation of the curriculum aimed at explicit digital fabrication in arts and crafts, I performed an evaluation of the prototype with four art educators.

The results of this study broaden our understanding of how art education perceives the use of digital tools in Norway in light of the changes made by policy makers. Furthermore, the results of this study suggest that art educators can be facilitated with a digital platform when introducing digital fabrication to comply with the curriculum. The work from this study shows that participants seem to favor familiar projects with the incorporation of technology. In addition, the results indicate that they would be interested in using the platform for their practice. The home page helped the teachers understand how the Micro:bit worked and its applications in arts education. There is still a need to present technical concepts, as terms such as *programming* are still new for art educators. The first task presented the teachers with a practical walk-through of digital tools and their first code. The second task appealed significantly to participants. This is due to the reiteration of familiar projects with the incorporation of technology. In addition, the implementation of animated instructions helped participants understand the technical assembly of components. There is a need to provide teachers with learning outcomes for each task to validate its purpose. The platform should contain other elements of digital fabrication, such as 3D printing in the resource page. Furthermore, the results indicate a need to supplement the platform with other existing practices in arts and crafts today. This can be achieved by reframing the platform to a community-based resource, where teachers and educational specialists can contribute with relevant projects to increase engagement in their field.

I hope to contribute not only by presenting my results, but also the documentation of my design process in regards of using research through design as a methodology. Furthermore, the contributions from this thesis will also come in the form of the findings of the preliminary interview and an extensive literature review on digital fabrication and computing in education. Finally, the following sections will come in the form of suggestions for future work, as well as the limitations of the study.

8.1 Limitations

This section presents and discusses the limitations of the study, excluding the limitations described in Section 7.5. These limitations may have affected the design of the prototype and the results to some degree.

8.1.1 Participants

There were 3 participants in the preliminary interviews, 4 in the evaluation of projects, and 4 in the evaluation of the final prototype. The project would benefit from looking at a variation of pedagogic perspectives, looking at different regions in the country. Furthermore, I was an acquaintance with one of the participants, which could have influenced their perception towards the research. Their relationship towards the author of this thesis may have impacted their attitude towards the study and influenced them to react positively. This should be regarded as a possible limitation.

8.1.2 Data Collection

This section follows through on the topic of participants. The research would have benefited from using other forms of data collection. Using the prototype in a realistic setting, for instance, a classroom would provide more reliable results. A systematic approach to collecting data would allow for a comprehensive analysis in the form of open coding. Another limitation is the data collected from the preliminary interviews, as I was not able to observe their practice due to pandemic restrictions. Their responses could not be representative of how they practice their work in the classroom and can therefore be considered a limitation. There is a possibility of participant bias considering that the evaluations of the possible projects and prototype have been performed in distributed meeting systems.

8.2 Future Work

This section outlines suggestions for future work for research in a similar scope. It builds upon the contributions that this research has provided. These suggestions are rooted in existing literature and available data from the design activities.

8.2.1 Expanding the platform for students

Results from the prototype evaluation suggest that the platform should be expanded to students at a later stage. It would be interesting to explore the notion of digital citizenship in a practical subject such as arts and crafts.

Exploring other applications of digital fabrication

In this study, I have limited digital fabrication in arts education to the use of motors and electrical components. This study suggests future work to look at alternatives to Micro:bit, such as makey makey[1] and adafruit[2]. Looking at additive manufacture and subsequent software suitable for second and third-dimensional models can challenge the current use of digital tools in art education.

8.2.2 Collecting more data

As with any research, it is always beneficial to collect more data, however, in this context it would be appropriate to gather more data on the activities that are practiced in schools today. This can be achieved by conducting observations at the location. In addition, conducting expert interviews with teachers and educative technicians can provide in-depth insight in to the other aspects of the research topic.

8.2.3 Sharing culture

As suggested earlier in this chapter, the prototype should be reframed to allow teachers and relevant educational resources to send projects and teaching materials to the platform.

[1] Makey Makey: `https://makeymakey.com/`
[2] Adafruit Express: `https://learn.adafruit.com/adafruit-circuit-playground-express`

This would also create a need to explore the potential of establishing a sharing culture in the arts education community.

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Appendix A
Preliminary Interview Guide

Introduksjon / Warm-up

- Introdusere temaet for masteroppgaven og grunnen til hvorfor vi har intervju.
- Spørsmål om erfaring for å sette grunnlag for ekspertisen
  - Hva er ditt arbeidsområde her ved HiØ?
  - Hvor lenge har du jobbet med kunst og håndverk?
  - Er du kjent med den nye læreplanen for kunst og håndverk

Hoveddel

Tema 1: Hva blir gjort i praksis i dag?

- Hvilke aktiviteter blir gjort/gjennomført i kunst og håndverk?
  - Hva er det som lages? Hva slags ressurser blir benyttet for å oppnå målet?
  - På hvilken måte(strategier) lærer man bort evnen til å produsere slike materialer?
  - Er det noe form for autonomi for barna i prosessen? Hvordan det i så fall?

Tema 2: Kreativitet og engasjement i læring (adresser «keychain syndrome»)

- Hvordan fremmer lærere kreativitet i fabrikasjon av materiale i kunst og håndverk
  Probes
  - Sløyd, Strikking, Malerier og teori
  - Hva er det du mener er viktigst når det gjelder læring i kunst og håndverk?
- Hvilken rolle mener du en lærer skal når det gjelder kreativitet i kunst og håndverk?
- Hva er deres erfaring med å bearbeide materiale på barne- og ungdomskoler i dag?
- Hvordan er din oppfatning av barnets læring og utvikling i kunst og håndverk?
- Har dere utfordringer med barn som ikke ytrer originalitet i deres verk? Hvilke metoder ville du har brukt for å heve nivået på kreativiteten i slike tilfeller?

Tema 3: Teknologi i kunst og håndverk

- Hvordan er det med digitale ferdigheter i dagens opplegg i emnet?
  - Har det blitt brukt noe form for teknologi i faget? Hvordan fungerer det i praksis?
    Probes: *3d printing, microbit, foto og media, presentasjoner makerspace tilbud*.

- Hvilke ressurser har du tilgjengelig når det gjelder bygging av materiale i dagens utdanning?
- Hvordan mener du en lærer kan tilrettelegge for bruk av teknologi kunst og håndverk?

Avslutning/Cool-down

«*I læreplanen for Kunnskapsløftet fra 2006 ble teknologi og design innført som flerfaglig emne i naturfag, kunst og håndverk og matematikk*.»

- Hva er din oppfatning av kunnskapsløftet og hva legger du i «teknologi» i forbindelse med kunst og håndverk.

Appendix B
Project Evaluation Guide

Formålet (Digital Fabrikasjon)

Utforske om de utvalgte oppgavene er egnet til bruk i undervisningen, og hvordan kan de tilpasse slik at det er gunstig for læreren og elevene.

Før presentasjon av Forslagene

- Introduser masteroppgaven, hensikten din med opplegget og hvilke teknologier du har fokusert mest på (Micro:bit).
  - Presiser at det er ikke noe krav for kandidaten å kunne noe om teknologien.
  - Fokus på det fysiske, digital fabrikasjon. (Du erstatter ikke noe, du fremhever det med teknologi).
  - Presenter kort om Micro; bit og hva den kan gjøre.

Hoveddel (For hver presentasjon av opplegg)

1. Generell oppfatning av prosjektet/oppgaven
   a. Hva tenker du om å gjennomføre en slik oppgave?
   b. Hva er din vurdering om bruk av digitale verktøy i denne oppgaven?
   c. Er det noe du ønsker å justere, legge til eller fjerne?
2. Klassetrinn og nivå
   a. Hvilken klasse mener du oppgaven kunne passe til?
   b. Hva er ditt inntrykk om vanskelighets nivået på oppgaven?

Avslutning (Etter presentasjon av alle oppgavene)

a. Hvordan kan teknologer legge til rette for at lærere kan være trygge på å gjennomføre oppgaver av slik natur?
b. I Tillegg til disse oppgavene, er det noe du ønsker å legge til?

Appendix C

Presentation of Possible Tasks for Arts Education

Evaluering av oppgaver i kunst og håndverk

Masteroppgave – Digital Fabrikasjon I kunst og håndverk

Fahad Said – Høgskolen I Østfold

Kort om masteroppgaven

- Utforske muligheter for fysisk digital fabrikasjon med hensyn til lærerplanen

- Etter 4. trinn: Prøve ut håndverkteknikker og digitale verktøy i skapende prosesser.
- Etter 7. trinn: Bruke programmering til å skape interaktivitet og visuelle uttrykk.
- Etter 10. trinn: Utforske hvordan digitale verktøy og ny teknologi kan gi muligheter for kommunikasjonsformer og opplevelser i skapende prosesser og produkter

Digitale ferdigheter

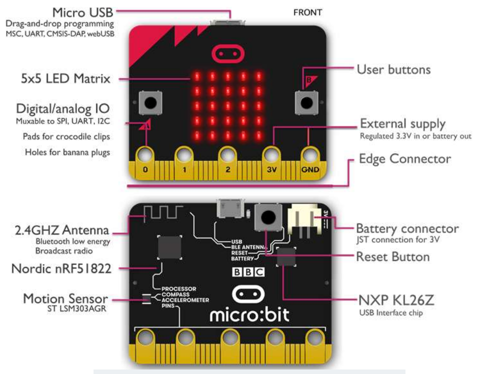
Digitale ferdigheter i kunst og håndverk innebærer å kunne bruke digitale verktøy og medier til inspirasjon, utprøving, dokumentasjon og presentasjon. Det innebærer også å bruke digitale verktøy og programmering i kreative og skapende prosesser. Kjennskap til regler om opphavsrett og personvern når man bruker egne eller andres bilder, filmer og skapende arbeid, er vesentlig på alle trinn. Utviklingen av digitale ferdigheter i kunst og håndverk går fra å bruke enkle digitale verktøy og medier, til å forme egne digitale produkter som skaper opplevelser og kommuniserer følelser, ideer og meninger.

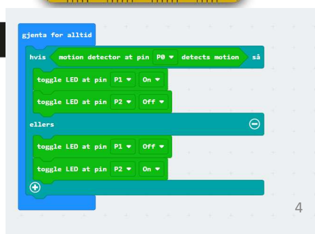
3

Micro:bit og bruksområder

Funksjonaliteter

- Lys (25 LED lys).
- To knapper.
- Bluetooth (Kan styres med mobiltelefon)
- Lettest å programmere på nettleser.
- Blokk programmering.
- Kan bruke eksterne komponenter slik som høyttalere, LED osv.





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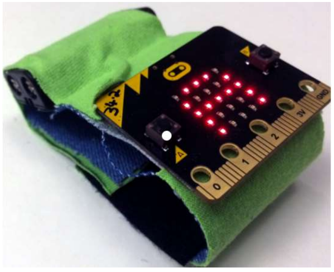
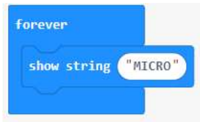
Forslag A: Smart "navnskilt" med Micro:bit

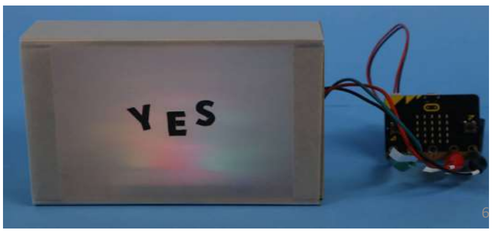
- Formål
  - Grunnleggende programmering.
  - Kombinere elektronikk og tekstil.
  - Kan også bruke andre materialler slik som papp.
  - For å gjøre øke nivået kan projsektet anvendes til en enkel «smartklokke».
- Eleven trenger
  - Micro:bit, batteri pakke.
  - Materiale til å sy sammen et beholder for microkontrolleren





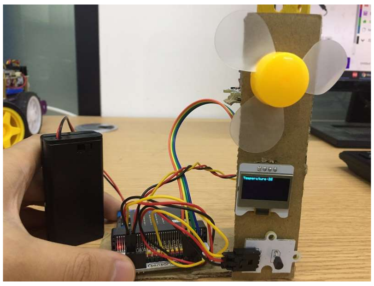
Forslag B: "Smart" nattlykt (lantern)

- Formål
  - Introdusere LED lys i fabrikasjon av verk.
  - Utføre en «teknisk» oppgave som kombinerer programmering og kopling av komponenter.
  - Eleven kan lage sin egen versjon av et nattlys ved å bruke materiale som ikke har nytte hjemme(esker, gamle aviser). Læreren kan fremme bærekraft gjennom dette.
- Eleven trenger
  - Micro:bit controller, batteri pakke, LED lys lenke.
  - Råmateriale: Papp, papir eller plast.



Forslag C: Enkel vifte med motor

- Formål
  - Introdusere enkel bruk av motor (og eventuelt andre sensorer).
  - Utføre en «teknisk» oppgave som kombinerer programmering og kopling av komponenter.
  - Muligheter for å gjenbruke materiale man ellers hadde kastet. (Plastflasker, papp osv.)
- Eleven trenger
  - Micro:bit, batteri pakke.
  - Råmateriale: Papp, papir eller plast.



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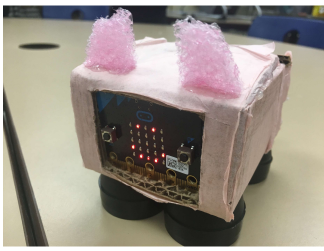
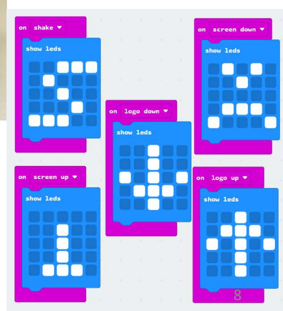
Forslag D: Levende“Dum”robot/kjæledyr

- Formål
  - Lage en skapende modell med teknologi i kjernen og samtidig Introdusere sensorer som medfølger elektronikken.
  - Bruke teknologi for å fremheve enkelte elementet med verket.
- Eleven trenger
  - Micro;bit, Batteri pakke.
  - LED lys, mini-høyttaler.
  - Materiale til å bygge modellen.





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Appendix D

Prototype Evaluation Guide

Material to be tested

Digital resource platform: A website that introduces teachers within arts and crafts.

Procedure

Share website with subjects beforehand. If restrictions allow it, provide the subjects with equipment that will help them go through the platform (Micro:bit, cables, motor).

Link to website: https://sites.google.com/view/mastersfahadhiof/home

Questions to ask during evaluation

- Does this website provide interest for you as an arts and crafts teacher?
  - *Probe: Home Page & Resource page*
- How do you perceive the presentation of the digital tools that can be used in your subject?
  - *Probe: Task pages and presentation of Micro:bit*
- In your opinion, does the platform fulfill its purpose? (Reference to the teaching curriculum)
  - *Probe: Difficulty of tasks, reference to examples of micro:bit in crafting projects.*
- Is there anything you are missing? (Resources, information, unclarified explanations)
  - *Probe: Resource Page and reference to curriculum.*
- How would you use this platform to educate your students in digital fabrication?
  - *Probe: Which task is best suited for you.*
- Anything you would like to add or supplement this platform? (potential improvements)
  - *Additional project ideas for Arts and crafts.*