Creative Coding at the arts and crafts school Robotti (Käsityökoulu Robotti)

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Abstract. The increasing use of digital technologies presents a new set of challenges that, in addition to key economic and societal viewpoints, also reflects similar use in both education and culture. On the other hand, instead of a challenge, digitalisation of our environment can also be seen as new material and a new medium for expression. This article examines creative coding both as a method to better understanding of digital structures, and as the ability for self-expression through digital technology. The research focuses on Käsityökoulu Robotti, a type of art school for children, which offers children teaching on art and technology. Through ethnographic research, this article examines how creative coding works as a teaching method in Käsityökoulu Robotti to promote both artistic expression and a critical understanding of technology.

Keywords: Art education, digital culture, digitality, peer learning, art +tech, education, creative coding, media education, critical thinking

1. Introduction

Digital technology is now part of everyday life. From work to leisure, the everyday tasks of sending messages to operating large infrastructures, digital technologies have replaced previous technologies and routines. Berry calls this change the post-digital era that signifies the intertwined and complex nature that digital technology now plays in the society (Berry, 2016). Post-digital refers not to the end of digital era or digitalisation, but to the to the current situation where digital technology is ubiquitous and complexly intertwined with everyday life (Berry, 2015,2016). The effects of post-digital are also reflected in art education (Knochel & Patton, 2014; Shaw & Wagelie, 2016; Wang, 2016) as well as children's everyday lives, as increasingly, more play and toys are becoming digitalised in some form or another. From cheap digital toys to augmented and virtual reality environments, digital technologies are now a consistent natural part of most children's habitats (McReynolds, 2017. Turkle, 2011).

Digital technologies differ from the previous technologies because of their programmed nature. The underlying codes present in digital technology allow a product or service to be programmed, reprogrammed, hacked, updated and analysed (Berry, 2016; Ceruzzi, 2012). Berry remarks that the programmable and reprogrammable

nature of digital technology (code) together with the flow of processes from a digital device to another, instills agency into the digital technology itself (Berry, 2016). Further, still, digital technology allows an effortless and invisible gathering of information. As such, digital technologies present questions of both power and ethics: Who decides how these products are programmed? Whom are they programmed for? Who owns and benefits from the collected data? (Author, 2016; Rushkoff, 2010; 2016) As a recent example, Internet-connected toys can now collect children's conversations and send them to companies to be processed and analysed, awakening even more concerns for privacy on an entirely new and more serious level (McReynolds et al., 2017).

The programmable nature of the digital technology demonstrates how the digital technology is malleable and can be seen to reflect both conscious and subliminal values of the programmer, a software company or a society's understanding of good code (Giroux, 2011; Lessig, 2009; Rushkoff, 2010). Therefore, the ability to understand code, the underlying base of digital technology, is a question of equality: Without comprehension of the surrounding digital structures, it becomes hard or impossible to critique or change them (Freire, 2016; Rushkoff, 2012) One of the challenges when responding to these questions is how to find ways to avoid a new kind of digital divide between those who understand the code and those who do not (Author, 2016). In that regard, this article proposes creative coding as a means of examining and understanding the structures of the digitally mediated world. This understanding, in turn, can partially help to prevent a greater digital divide. As such, this article suggests creative coding not only as creative use of the code but as a one way to empower children in the post-digital era.

The intertwined and complex nature that exists between humans and digital technology reflects both art-making and expression. In the post-digital era, using digital technologies as a way of self-expression should not be considered as a specialty, but instead as a significant medium to use to comment on the post-digital world. As with any artistic medium, creative coding offers a unique set of tools that can express views that otherwise might be difficult to communicate (Cox, 2013). This article focuses on art & craft school Robotti (Käsityökoulu Robotti), a school that gives education on the intersection of art and technology with interest in empowering children in the digital domain (Käsityökoulu Robotti, 2017). In particular, this article focuses on how Robotti uses creative coding as its teaching method. 2. Creative Coding
Using digital technologies and programming in visual arts has an extensive history. Greenberg traces it to the birth years of digital computing in the late 1950's (2007); moreover, art and technology share an even longer history as, noted for instance, by Shanken (2001). Even though digital tools, in general, have now migrated into the arts (Berry, 2015; Bishop, 2012), it can be argued that programming has never been mainstreamed in the art world (Cox, 2013; Taylor, 2014).

Creative coding is described as a type of programming where expression is more important than function. (PBS, 2013) Knochel and Patton liken creative coding to any

other practice undertaken in an art studio: By learning the basics of the medium, one can start to express and even break the rules (Knochel & Patton, 2015). Some programming languages, programming environments, and even devices have already been built especially for creative coding. (For example:processing.org, openframeworks.cc, arduino.cc, rasperrypi.org) Common to all of these is that they have transformed programming into something one can today experiment with ease. Furthermore, these platforms, as well as the culture of creative coding, expand programming from the act of writing code to creative use of digital technologies in general. Instead of just building software, many projects, like Arduino and Raspberry Pi, add electronics, sensors, and interactivity to the domain of creative coding. This expansion provides space for greater exploration and creative expression (Author, 2016; Greenberg, 2007).

2.1 Creative Coding as pedagogy

This current research effort suggests that creative coding can be both an artistic use of code as well as a method for gaining an understanding of the surrounding digital world. These two modes are not separate, but rather intertwined with each other. Through coding, one creates art, and yet at the same time, one shapes the connection to the world being created. As such, this research suggests creative coding as a pedagogical method for raising more awareness through the act of creating in the digital realm.

The art educational view in this research takes inspiration from the experiential art interpretation (Erickson, 1999; Kolb, 2014 Räsänen, 2000). Furthermore, this article aligns with art educations role as creating and developing creative and critical thinking, as well as exploring the tonalities and structures within the culture (Efland et al., 1996; Ettinger, 1988; Marner & Örtegren, 2014; The Finnish Association of Art Schools for Children and Young People, 2013). One of the benefits of art education is its interplay between individual experiences and abstract concepts (Parsons, 1987; Räsänen, 2000). This interaction between the abstract and the concrete and the ability to anchor abstract concepts to experience becomes crucial when dealing with the digital world, which is abstract by its very nature (Author, 2016; Lessig, 2009; Rushkoff, 2010; 2013). From this perspective, artistic use of code can be seen as a way to substantiate abstract concepts in each doer's everyday life.

Another significant aspect of art is its power to bring forth questions that might otherwise be hard or impossible to formulate and to lift everyday themes under particular introspection (Dissanayake, 1992; Noë, 2015). In the current post-digital world, the questions about the conditions of post-digital are substantial. The sort of commentary, critique, and understanding of the digital world that creative coding can bring to the surface are of great importance. Cox suggests that code, like language in general, "evokes complex processes through which multiple voices can be expressed, modified, and further developed"(Cox, 2013,p.16). As such, the artistic use of code

should be seen as a meaningful medium for commenting on the contemporary world alongside other known and long used art mediums.

In this article the meaning-making method of creative coding is also seen through phenomenology. The Finnish craft professor, Kojonkoski-Rännäli, following Heidegger, considers making by hand the basis of human existence: Making is not only a creation of an object; it is also active sense-making that relates one to the surrounding world (Heidegger, 1952; Kojonkoski-Rännäli, 1998). Digital world can often appear distanced and abstract(Fuller, 2008). In this framework, creative coding can be seen as a process that creates a tangible and embodied understanding of digital construction. Although the notion of coding as an act of making by hand is debatable as it does not involve a direct connection with the material, but rather a connection to an intermediary medium of code. However, it can be argued that code could be seen as the very material of digital technology, in its way it constructs the digital world (Berry, 2016; Lessig, 2009; Rushkoff, 2010). Moreover, many programmes identify themselves to artisans (Buechley & Perner-Wilson, 2012; Cox, Mclean, & Ward, 2005; Greenberg, 2007). Even further, programmers can be seen, in Heideggerian terms, to 'tend' the digital world highlighting attachment and sense of relation to the digital world. (Heidegger, 1952; Kojonkoski-Rännäli, 1995). For instance, Free software movement is not only a political and ideological movement, but it also cares for the way in which we construct the digital world (Stallman et al., 2009; Ratto, 2011).

2.2 Code Literacy and Creative Code

As discussed in the introduction, one of the challenges of ever-increasing digitalisation is the inequality between those who can and those who cannot code. However, requiring everyone to learn master coding, a rather specific skill, may be too much to ask. Nevertheless, when one considers the ubiquity of the digital, coding could be seen as being transformed from a particular skill to a democratic right (Lessig, 2009; Rushkoff, 2010; Stallman et al., 2009). In essence, the need for individuals to learn programming could be likened to literacy: It is more about the ability to read and write than using those skills to produce a masterpiece. Code literacy can be linked to several theories and traditions, such as media education (Rushkoff, 2010; Saariketo, 2015), software studies (Fuller et al., 2008), and even societal studies of the digital (Berry, 2016; Hayles, 2010). In general, code literacy refers to the understanding of the prevailing biases and laws in digital technologies as well as to the understanding of the malleability of code, namely, that coded structures are not invented, but rather created. As such, code is political, commercial, cultural, and ideological (Author, 2016; Lessig, 2009; Rushkoff, 2010; 2012). This article discusses how creative coding can benefit the understanding of digital technologies and its underlying code.

2.3 Other cultural perspectives related to creative coding

One of the cultural aspects of creative code is its involvement in the Free/Libre and Open Source Software (FLOSS) ideologies. The general idea of FLOSS is that the

ability to see how a program is built is a democratic right. Without seeing how a piece of software is written, we have no way of knowing what the software does, nor the possibility to change it.(Stallman et al., 2009; Vaden, 2005). Regarding creative coding, FLOSS means the ability to benefit from and build on the work of others. For example, machine learning or other sophisticated algorithms may be out of reach for the average creative user; yet with openly usable code, anyone can benefit from using these techniques (See, for example, https://aiexperiments.withgoogle.com/)

The maker movement is a broader cultural movement that focuses on the resurgence of making by hand, coupled with an interest in the new digital technologies for production and sharing (Anderson, 2012; Blikstein & Krannich, 2013; Dougherty, 2012; Halverson & Sheridan, 2014; Hatch, 2013; Martinez & Stager, 2013). Creative coding shares that same attraction to digital technologies as well as an interest in making by hand (Author, 2017). Underlying both the maker movement and creative coding is an interest in code, digital technologies and also the world created using that code (Buechley & Perner-Wilson, 2012; Cox, 2013; Lang, 2013).

Creative coding as a culture, as well as the maker movement and the FLOSS-culture, bring forth the cultural, political, economic, legislative and societal aspects of digital technologies. As a culture and practice that is closely linked to FLOSS and the maker movement, creative coding presents educators with opportunities that go well beyond the usual understanding of coding.

3. Research Subject and Methods

As mentioned in the introduction Robotti is a non-profit organisation that focuses on the fusion of art and technical education. Robotti was founded in 2012 with the objective of establishing a “child-friendly hacker space.” Currently, one of the core ideas of Robotti is to provide continuous teaching in the field of art and technology to ”encourage children for creative and adventurous inquiry in the digital domain through art” (Käsityökoulu Robotti, 2017).

Käsityökoulu Robotti identifies itself with the art school system in Finland. Seeking to educate children on both the artistic use of digital technologies as well as the culture surrounding it, Käsityökoulu Robotti sees itself to deviate from code school projects (code.org, in Finland koodikoulu.fi). All of the teachers in Käsityökoulu Robotti have gained education in fields related to the arts or crafts, many of them being art educators. Figure 1 situates Robotti in its thematic context based on the topics that were raised in interviews, questionnaires, and informal discussions during this particular research effort.

3.1 Research Methodology

The research into Robotti was a longitudinal ethnographic process for the five years of Robotti's existence. The ethnographic material consists of direct observations, as well as several field notes and many informal discussions at Robotti. During the research, project questionnaires were given to both to students and teachers at Käsityökoulu Robotti. In the final year of the research, interviews were arranged with the central teachers at Käsityökoulu Robotti (3 Interviews), and also an online questionnaire was given to all the teachers of Käsityökoulu Robotti. Further, during the research process, several videos and photographs were shot; however, they are used only for illustrative purposes in this current article.

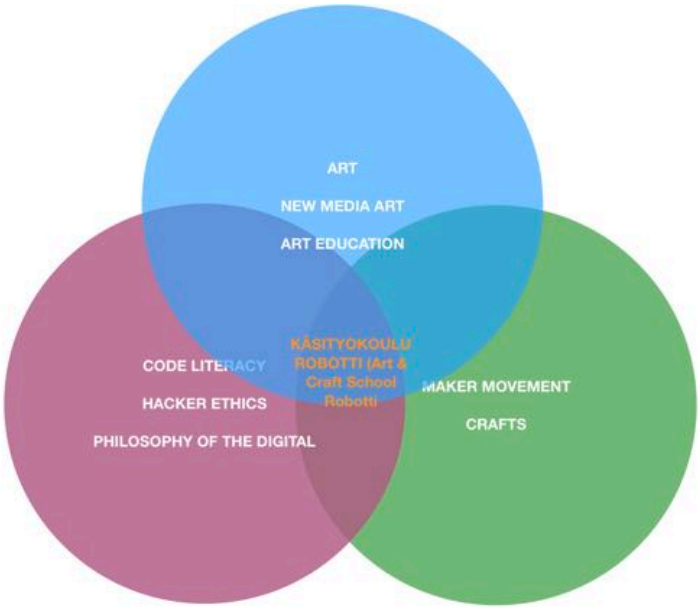


Diagram 1, Situating Käsityökoulu Robotti in its thematic context

The results gathered from Käsityökoulu Robotti on creative coding were contrasted, as well as their perspective broadened, by two interviews with professors' specialising in digital art education and new media. Dr. Robert Sweeney is an Art Education Professor at the Indiana University of Pennsylvania, who specialises in digital culture in art education. Dr. Ryan Patton works at the Virginia Commonwealth University as an Assistant Professor and has specialised in new media art education and created the currentLab, a new media art education research initiative (http://currentlab.art.vcu.edu). Further still, online surveys given to students and teachers' taking

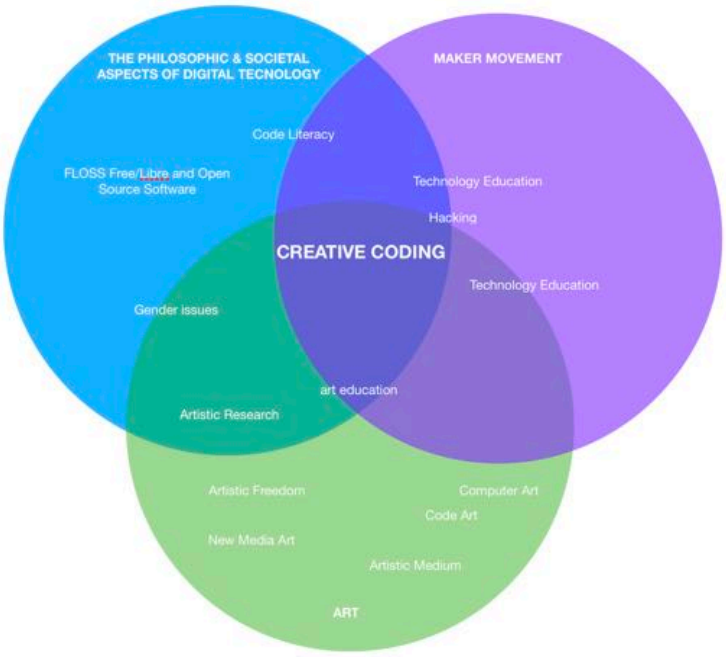


Diagram 2. Situating Creative Coding in its thematic context

creative coding classes at the University of Turku were gathered. Through close reading, these materials were analysed according to their relevance and perspective on creative coding. Due to the newness of the school, no clear data on the children's understanding of creative coding, nor the development of that understanding, could be seen. Therefore, this article only uses the questionnaires and remarks from children for illustrative purposes.

3.2 Researcher Bias

The collected materials present a historical perspective on the development of Robotti and the thinking behind its declared role. However, at the same time, the researcher acknowledges the possible subjectivity as well as biases inherent in ethnographic research (LeCompte, 1987). Thus, this research offers one interpretation of the teaching in Robotti. However, this potential weakness of the research is partly compensated for by hearing the teachers both in an interview as well as an anonymous questionnaire and contrasting their views to the theories presented here. Furthermore, interviews with art education professors expert in the field were added to broaden and question the perspective.

4. Findings and Discussion

Analysis of the research materials offers a diverse picture of the teaching at Käsityökoulu Robotti. This article uses the concept of creative coding to talk generally about the teaching methods used in Robotti and the theories behind them. From this context, a shared general direction and purpose of Robotti can be seen among all the teachers at Robotti. For instance, all the three interviewed teachers saw art as an essential educational method for examining digital technology. Two teachers saw art as a differentiator between Robotti and, for example, the code schools. Art was said, *"to give more freedom to explore digital technologies as well as situate themselves in the digitalised world than, as a comparison, mathematics or technology education can offer them"* (Interview, 17.3.2017). Even though many questions and possible pathways arose during the research project, for instance, gender issues in technology education and disability and technology, the primary question of this research project was to examine creative coding as a teaching method.

4.1 The Concept of Creative Coding

All of the teachers in Robotti are familiar with the term creative coding, although each teacher emphasises different aspects of creative coding. Creative coding can thus be seen as a way to deal with the understanding of our digitalised environment to a one person, and for the other person, creative coding can be perceived as more of an issue of beautiful code. The figure (figure 2.) below illustrates the three top perspectives and sub-themes of creative coding that emerged through a close reading of the research material during this research project. The position of each sub-theme is displayed as it relates to the three main perspectives. For example, while the teachers mostly talked about artistic research regarding the perspective on art, there were also philosophic and societal aspects of that code present. However, the position of the sub-themes does not present the exact relationship of the sub-themes to each other but instead is a way to visualise the approximate position of each sub-theme overall.

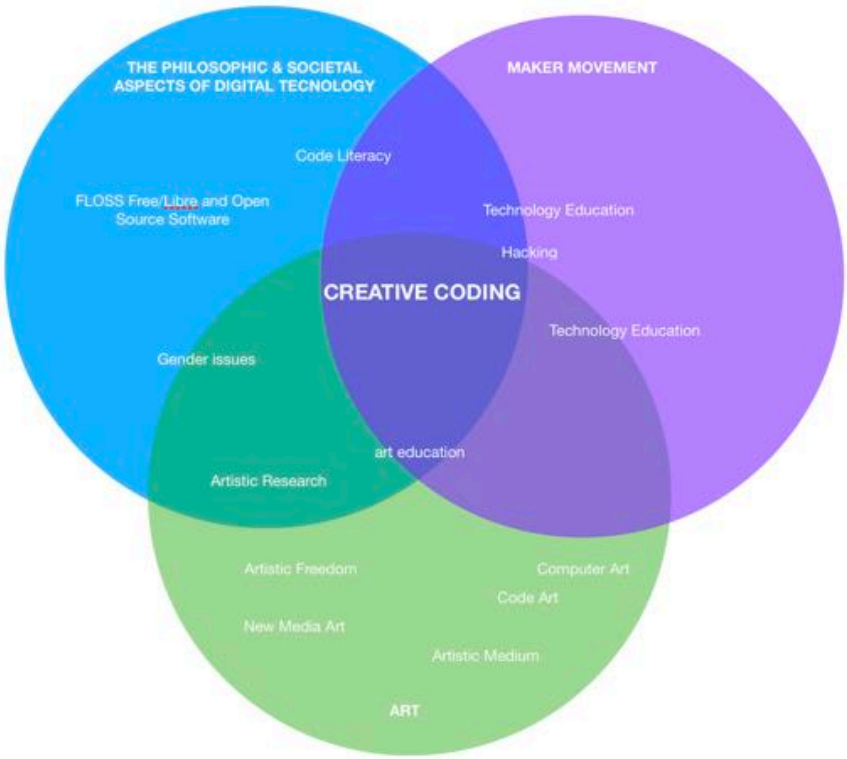


Figure 2. Situating Creative Coding in its thematic context

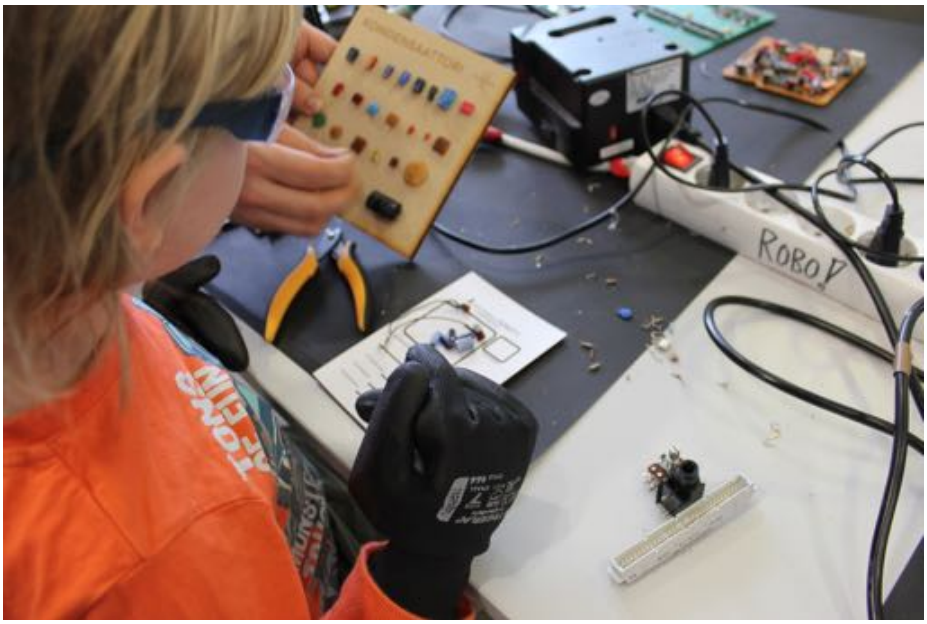
4.2 Code as a Freedom and a Right

In the philosophical and societal context, creative coding acts as a method to concretise the questions of code into the everyday lives of children as well as to questions of code literacy and empowerment in the post-digital era (Author, 2016; Morozov, 2014; Rushkoff, 2010; 2013; 2016; Stallman et al., 2009). Among the teachers of Robotti, creative coding was seen as a liberating method, differing from the more rigid engineer approach and thus making it easier to deal with the ethical and societal questions related to digital technologies. One teacher described this method as a technology unchaining itself from its utility and instead emphasising the feeling of the technology. Moreover, the hands-on method of creative coding was seen to bring forth better comprehension of the digital world. In an interview, one teacher expressed this perspective as follows: *"Creatively examining our coded structures can evoke a critical understanding of these surroundings"*(Interview 17.3.2017). Another teacher linked his view more directly with the ideologues of Free Software (FLOSS), stating that through coding and specifically through using and altering other people's code, the importance of free software becomes easier to demonstrate and understand (Interview 6.7.2017).

4.3 Digital Handicrafting

The second perspective approaches creative coding through the maker movement, which includes the more craft-like qualities of creative coding. All the interviewed teachers at Robotti identified the school in some way with the maker movement. Likewise, all the interviewed teachers, as well as those who answered the questionnaires, saw making by hand as an essential skill close to Kojonkoski-Rännäli's phenomenological view (1995), that was considered to be an essential way of building a better understanding of the possibilities of digital technology. One teacher stated that building something from scratch integrates that child more into the world s/he is building (Interview 17.3.2017).

On the questionnaire, one of the teachers in Robotti wrote that the open-ended discovery and interest in taking things apart are aspects that he recognises in his teaching (Online Questionnaire answered 12.12.2014). Teachers also saw the using of tools and opening devices as giving children the courage to investigate digital domain. One teacher stated that one child was astonished that she was allowed to open devices even though there was a "Warranty void if opened" sticker on the back of it (Interview 6.7..2017). Other teacher talked about "creative tool use" by which he meant that during the school year children had become proficient enough with tools that they could implement standard pliers instead of side-cutting pliers or try a lead in a circuit without instruction or fear (Interview 17.3.2017).



Student exploring digital components and creating his own electronic ”herbarium”. Photo by Roi Ruuskanen 2016.

4.4 Artistic Freedom

The third perspective looks at the creative coding through art and art education. Based on interviews, questionnaires, and notes from the teacher meetings, teachers accentuated the adventurous and investigative role of experiental art education (Parsons, 1987; Räsänen, 2000) and postmodern art education (Efland 1996; Ettinger, 1988). For instance, one teacher described the open-ended inquiry as a helpful attitude: *”I think that the art educational perspective is accomplished best through attitude. It allows for experimentation and mistakes are permitted. I try to make failures into observations and to courage to try again. Art education allows for creating and making without being an expert in the field.”* (Interview 7.3.2017). Furthermore, art education was seen as diminishing the preconceptions toward technology and at the same time evoking more balanced and even critical thinking of technology (Berry, 2014; Bogost, 2007). For instance, one teacher told they had listened to electricity through the speaker, rather than measuring that same electricity with a multi-meter. The teacher saw this listening effort as empowering an abstract digital environment by bringing the digital to sensory experience (Interview 17.3. 2017). Other teacher mentioned the importance of beautiful code: *”Even if no one sees it, the way the code is written can be substantial and have an effect on the feeling of the work”* (Interview 6.7.2017). Another teacher stressed the value of a piece of well-thought-out artwork that can express the maker's thoughts, feelings, or opinions (Interview 21.6 .2017).

In sum, for the teachers at Robotti, creative coding appears to be a technique as well as a framework for art making and art education, which enables both teacher and student to leave both the pre-conceptions and the misconceptions about the digital technology behind and thereby approach digital technology from a much more personal perspective.

Students interactive art work. Photo by Roi Ruuskanen 2017.

4.5 The Challenges of Combining Art and Digital Technology

In general, both students and teachers appeared satisfied with the teaching in Robotti, although teachers did mention various difficulties. One of the most common problems among the teachers was the dichotomy between open-ended discovery and a strict top-down style of teaching. For example, programming is a technology that requires that some rules be followed to produce an actual outcome. This following of instructions was difficult for some students and appeared tedious to some teachers. In the questionnaires, teachers wished for more guidance on where to draw the line between helpful, practical advice and creative discovery. Another common difficulty was finding ways to support the students, so they would have the courage to explore and try independently.

The data collected from the students and their parents were erratic and too insufficient to draw broader conclusions, but an analysis of the questionnaires, the artwork

as well as the field notes, appeared to be in line with the teachers' thinking. As an example, the children's more technologically oriented fantasy wishes at the beginning of the school year, such as creating walking and talking destroyer robot, had morphed into more concrete thoughts about repairing a broken RC (radio controlled) car or creating an interactive art installation. Few students stated that they now could see programming everywhere and wondered how it had been built. Concerning the art, some students indicated that they now understood that art does not only have to be something made with pens and brushes, but it can, for instance, be a programmed effort.

Another set of common problems was the preconceptions of digital technologies in general, generally seen as misguided by popular culture. For example, for some children, coding was a magical process that required supernatural skills, and/or hacking was something dangerous linked to terrorism or explosions. On the other hand, contemporary computer games and apps are now so sophisticated that the gap between them and the reality of what one can do alone becomes disappointing. In Robotti, one way to overcome these challenges was to create a shared goal for the semester in the form of an exhibition. The exhibition gave students enthusiasm to concentrate on their projects, even though the project would not have met their expectations at the beginning (Interview 21.6 .2017). Another teacher added that the exhibition also alleviated parents expectations and in that way students expectations (Online questionnaire answered 12.12.2014). Unfortunately, in an informal meeting, two teachers stated that some students do drop out because of their expectations had not been met.

As the teachers in Robotti are a somewhat homogenous group, they share similar ideologies without necessarily much critical thought ever expressed about these ideologies. To compensate for this bias, this research also interviewed two professors who were familiar with creative coding as well as giving a questionnaire directly to the participants of a creative coding course at the University of Turku. This group included both university students and arts and craft teachers already working in the field. The analysis of these materials coincided with the findings from Robotti and revealed new perspectives on creative coding.

The ubiquitous nature of digital technologies, as well as the need for education to discuss the nature of this ubiquity, was widely recognised. In general, creative coding was associated with the ability to generate critical thinking and an understanding of digital technologies. One teacher who took part in the creative coding course stated that learning programming in this way helped her to relate to digital technologies as well as see the importance of teaching programming in the basic curriculum (Finland recently started teaching programming as a part of the basic curriculum.) (Online questionnaire answered 10.11.2016). Dr. Patton and Dr.Sweeney offered game studies as an alternative perspective into creative coding (Interview 6.10.2017, 9.10.2016). For instance, Dr. Sweeney presented an example of how investing in designing one's own computer game can encourage a student to seek new ways to program that game to make it better.

One of the most common frustrations among all was the complexity and technicality of digital technologies. In particular, there was a fear of incompetence when surrounded by increasingly evolving digital technology and the uncertainty of not knowing where to start with the digital technologies. Dr. Sweeney indicated that critical thinking, as well as some technological knowledge, is needed among art educators to adjust their teaching accordingly. Indeed, the place and purpose for implementing digital technologies in art education should be most carefully considered (Interview 6.1.2016). Some of the questions raised by the interviewees as well as those who answered the questionnaire were: How much knowledge should one have of the technological foundations of digital technologies, or how much understanding should one have of the conventions and hierarchies of programming? Moreover, how much "artistic freedom" can one take with the boundaries of digital technology? In the example on "creative tool use" the teacher in Käsityökoulu Robotti remarked on a situation where the student independently tried to couple a LED light parallel to a direct current (DC) motor without a resistor: This coupling produced the wanted effect (LED light works) but still wasn't correctly coupled (Interview 7.3.2017). Should the teacher then delve deeper into electricity and talk about current, voltage, and resistance, or should the teacher leave the project as it is because it now does work?

Further still, if knowledge of electricity is required, then can one presume art educators will have this kind of knowledge? Dr. Sweeney and Dr. Patton pointed out similar problems when using digital software in general, i.e., making movies or animations, or editing using a photo editing application. All require some knowledge of their operations and even more to be able to understand their inner workings or advanced tools. How much technological guidance is needed in art education, and does that guidance and the choices of material hinder the reciprocity that is needed between experiential knowledge and abstract concepts? The answers to these questions will shed further useful light on the development of art education.

5. Conclusion and Future Research

This article examined creative coding as a method that combines the critical examination of our coded structures and its functions as an artistic tool to create art using digital technologies. Creative coding is widely understood as the creative use of programming where expression outweighs function. This article broadens that definition to include the critical inspection of digital technologies and the interplay between the individual experience and the abstract concepts that are so inherent in art education. The research here focused on the ways that creative coding is implemented for successful teaching at the Käsityökoulu Robotti.

The primary outcome of this research is the beneficial use of creative coding to make digital technologies easier to understand. Creative coding was seen as giving space and freedom to students so that they can find their position regarding these digi-

tal technologies. Using creative coding was also seen as allowing the inspection of digital technologies from new, maybe less common, angles of analysis. As one teacher in Robotti said, it is great to be able to *"collide students with themes and perspectives they would not otherwise ever explore"* (interview on 6.7.2017). The space for exploration was in the best cases also seen as giving students self-reliance and the courage to dig deeper. On the other hand, this perceived freedom was seen as challenging, as there are no clear guides as yet to follow or even precise places to start.

As this research focused mostly on Käsityökoulu Robotti and the concept of creative coding is indeed a novel one, further research is still required. Methods for using the different aspects of creative coding can be developed further by providing art educators easier access to creative coding. In sum, creative coding can prove to be a unique, valuable and exciting way to approach digital technologies. It offers multiple perspectives, such as the philosophical and societal aspect or the maker movement aspect. This focus can help each teacher when choosing an approach that is the most comfortable for her and her students.

References

Author (2017, 2016).

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

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

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

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

Bishop, C. (2012, September). Digital Divide. *ArtForum International*.

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

Bogost, I (2007) *Persuasive games: The expressive power of videogames.* Cambridge, MA: MIT Press

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

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

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

Cox, G., McLean, A., and Ward, A. (2004). Coding praxis: Reconsidering the aesthetics of code. In (Goriunova, O. and Shulgin, A., eds), *read_me Software Art and Cultures*, (pp. 161-174).

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

Dissanayake, E. (1992). The Core of Art: I*n Homo aestheticus, where art comes from and why.* New York: The Free Press. (pp. 1–26).

Efland, A., Freedman, K., & Stuhr, P. L. (1996). *Postmodern Art Education.* National Art Education Assn.
Erickson, M., & Räsänen, M. (1999). *Building Bridges, Experiential Art Understanding: A Work of Art as a Means of Understanding and Constructing Self. Studies in Art Education,* 40(4), 381. http://doi.org/10.2307/1320557
Ettinger, L. F. (1988). Art Education and Computing: Building a Perspective. *Studies in Art Education,* 30 (1), 53. http://doi.org/10.2307/1320652
Fuller, M., Goffey, A., Robinson, D., Pold, S., Kittler, F., Mackenzie, A., et al. (2008). *Software Studies.* (M. Fuller, Ed.). MIT Press.
Freire, P., Freire, A. M. A. 1., & de Oliveira, W. (2016). *Pedagogy of Solidarity.* Routledge. http://doi.org/10.4324/9781315422817
Giroux, H. A. (2011). *On Critical Pedagogy.* Bloomsbury Publishing USA.
Greenberg, I. (2007). *Processing*. Berkeley, CA: Apress. http://doi.org/10.1007/978-1-4302-0310-0
Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), (pp.492–494). http://doi.org/10.17763/haer.84.4.b1p1352374577600
Hatch, M. (2013). *The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers.* McGraw Hill Professional.
Hayles, N. K. (2010). *My Mother Was a Computer.* University of Chicago Press.
Heidegger, M. (2009). *Vortrage und Aufsätze (Pfullingen)* (11 ed.). Stuttgart: Klett-Cotta. Original work published 1952.
Knochel, A. D., & Patton, R. M. (2015). If art education then critical digital making: Computational thinking and creative code. *Studies in Art Education.*57 (1), (pp.21-38):
Knochel, A. D., & Patton, R. M. (2014). As we may publish: Digital scholarship and the future(s) of art education. *International Journal of Education Through Art*, 10(3), (pp.269–285). http://doi.org/10.1386/eta.10.3.269_1
Kojonkoski-Rännäli, S. (1995). *Ajatus käsissämme. Käsityön käsitteen merkityssisällön analyysi.* Turun yliopisto, Rauman opettajankoulutuslaitos. Nide 109 / Turun Yliopiston julkaisuja. Sarja C.
Kolb, D.A. (1984):. Experiential learning: experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall.
Käsityökoulu Robotti (2017) *Art & Craft School Robotti.* Retrieved January 16, 2018, from https://www.kasityokoulurobotti.fi/swe-eng/
Lang, D. (2013). Zero to Maker. Sebastopol: Maker Media.
LeCompte, M. (1987). Bias in the Biography: Bias and Subjectivity in Ethnographic Research. *Anthropology & Education Quarterly*, 18(1), (pp. 43-52). Retrieved from http://www.jstor.org/stable/3216340
Code 2.0
Lessig, L. (2010). *Code 2.0.* New York: Basic Books.
Martinez, S. L., & Stager, G. (2013). *Invent to Learn.* (C. Sinclair, Ed.) (1st ed.). Constructing Modern Knowledge Press.
McReynolds, E., Hubbard, S., Lau, T., Saraf, A., Cakmak, M., & Roesner, F. (2017). *Toys that Listen* (pp. 5197–5207). Presented at the 2017 CHI Conference, New York, New York, USA: ACM Press. http://doi.org/10.1145/3025453.3025735
Marner, A., & Örtegren, H. (2014). *Education through digital art about art. International Journal Of Education Through Art,* 10(1), (pp.41-54).
Morozov, E. (2014). *To Save Everything, Click Here.* New York: Public Affairs.
Noë, A. (2015). *Strange Tools, Art and Human Nature.* New York: Hill Wang.

Parsons, M. J. (1987). *How We Understand Art: A Cognitive Developmental Account of Aesthetic Experience*. Cambridge University Press
PBS, PBS Off. (2013). *The Art of Creative Coding.* Retrieved 12.3.2015 from: http://www.pbs.org/video/-book-art-creative-coding/
Rushkoff, D. (2010). *Program Or Be Programmed.* New York: OR Books.
Rushkoff, D. (2012, November 13). *Code Literacy: A 21st-Century Requirement.* Retrieved March 12, 2015, from http://www.edutopia.org/blog/code-literacy-21st-century-requirement-douglas-rushkoff
Rushkoff, D. (2013). *Present Shock.* New York: Penguin.
Rushkoff, D. (2016). *Throwing Rocks at the Google Bus.* London: Penguin UK.
Räsänen, M. (2000). *Sillanrakentajat [Bridgebuilders].* Helsinki: Publications of the University of Art and Design, A 28.
Saariketo, M 2015, Reflections on the question of technology in media literacy education. in S Kotilainen & R Kupiainen (eds), *Reflections on media education futures: contributions to the Conference Media Education Futures in Tampere, Finland 2014.* The International Clearinghouse on Children, Youth and Media, University of Gothenburg, Nordicom, Göteborg, (pp. 51-61). International Clearinghouse on Children, Youth and Media. Yearbook, vol. 2015
Shanken, E. A. (2001). *Art in the information age: Technology and conceptual art.* Leonardo 35 (4), (pp. 433-438).
Shaw, D., & Wagelie, J. (2016). Studying artworks and their digital copies: Valuing the artist's aura. *International Journal Of Education Through Art*, 12(1), (pp.57-69).
Stallman, R. M., Gay, J., & Lessig, L. (2009). *Free Software, Free Society.* Boston: Free Software Foundation.

Taylor, G. D. (2014). *When the Machine Made Art.* Bloomsbury Publishing USA. http://doi.org/10.5040/9781628929980
The Finnish Association of Art Schools for Children and Young People. (2013). *Basic Education in the Arts in Finland.* Retrieved from: http://whm13.louhi.net/~youngart/wp-content/uploads/ 2013/09/Basic-Education-in-the-Arts.pdf
Turkle, S. (2011). *Alone together : why we expect more from technology and less from each other.* New York: Basic Books.
Vaden, T. (2005). Digital Nominalism. Notes on the Ethics of Information Society in View of the Ontology of the Digital. *Ethics and Information Technology,* 6(4), (pp. 223–231). http://doi.org/10.1007/s10676-005-0350-7
Wang, T. W. (2016). The landscape of websites for art education and a portrait of their designers. *International Journal Of Education Through Art*, 12(2), (pp. 195-210).