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TechArt Learning Practices for 1st to 3rd Grade in Danish Schools

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Abstract: This paper reports on six prototypes developed for integrating digital technology and computational thinking into Danish visual arts education. We discuss the learning potential for TechArt integration based on our experiences developing the prototypes. The prototypes came about as a part of the national experimental project Technology Comprehension (2019–2020) in which the implementation of digitalisation from 1st to 9th grade took place partly by constructing a new school subject named technology comprehension and partly by integrating digital technology into selected school subjects (Buhl, 2019). For one of the chosen school subjects, visual arts education, suitable prototypes were developed for teaching 1st to 3rd grade. Digital technology has officially been a part of visual arts as a school subject since 1991 (Danish Ministry of Education, 1991), although experimental environments in Denmark explored technology beforehand (e.g. Skov, 1988). Technology has a dual role: it is a tool for artistic expression (i.e. students experiment with devices and applications) and a topic for artistic expression (i.e. students inquire about and explore the societal implications of the man–machine relationship in a world characterised by social media, algorithms and mobile technology). Six prototypes were developed based on curriculum-informed activities in combination with principles related to programming, construction, digital design and social empowerment. The six prototypes are entitled (1) Pattern and Shape, (2) Exploring Colour, (3) Animated Stories, (4) Pixel Art In Art Programmes, (5) Nasubi Gallery and (6) 3D Sculpture. They represent objectives to facilitate learning, both visually and digitally. Our paper provides short descriptions of the six prototypes, presents the interdisciplinary and pedagogical ideas behind them and discusses the future integration of technology comprehension into visual arts as a school subject. The theoretical framework draws upon insights from studies of contemporary visual arts pedagogy (e.g. Rasmussen, 2017; Tavin, 2015), visual culture (e.g. Mirzoeff, 2013; Rogoff, 2008) and digitisation (e.g. Sack, 2019). Contemporary visual arts education in Denmark is driven by learning through visual aesthetic practice as well as developing skills within the field of art and visual culture, and a core learning objective is gaining a critical perspective on visuality (Buhl & Skov, 2019). Based on the work with the six prototypes, we argue that digitisation of art-making facilitates the potential to integrate computational thinking and social empowerment.

Keywords: technology comprehension, visual arts education, programming and construction, learning design, empowerment

1. Introduction

Technology comprehension is a hot topic in the Danish educational agenda. For the period of 2018–2021, the Danish Ministry of Education (2018a) launched a national experimental project to test a new school subject, technology comprehension, for 1st to 9th grade in 46 schools. Prior to the national experimental project, a small-scale experiment with technology comprehension as an elective school subject was conducted and reported in secondary schools (Danish Ministry of Education, 2018b; Tuhkala et al., 2018). Furthermore, developmental work was performed to explore activities with technology (e.g. Hansbøl & Ejsing-Duun, 2017; Nørgård & Påskesen, 2016). Based on a ministerial commission, an expert group formed common learning objectives for technology comprehension as a single school subject and as part of existing school subjects (Danish Ministry of Education, 2018b). Four areas are stated for overall competence in technology comprehension:

- *digital empowerment*, comprising critical reflection on the implications of digitalisation;
- *digital design and design processes*, comprising planning and iterative processes in a user context;
- *computational thinking*, comprising the analysis, modelling and structuring of data and data processes; and
- *technological capacity building*, comprising the mastering of computer systems, digital tools, attached languages and programming (Danish Ministry of Education, 2018b).

As part of one of the school subjects selected for technology comprehension integration in the national experimental project, visual arts education professionals were involved in the development of learning content for teaching technology comprehension. Specifically, they were involved in the development of six prototypes for teaching visual arts in elementary school (1st to 3rd grade). In order to help students gain overall competence, the learning objectives for visual arts were focused on mastering construction and programming activities, analysis, and use studies. This paper presents and discusses the prototypes from the perspective of contemporary visual arts and technology comprehensions contribution to each other's learning domains respectively.

2. TechArt - a hybrid of technology and visual arts

The ministerial commission and digital expert group for technology comprehension who formed the common learning objectives for visual arts drove the framing of this educational initiative. The visual arts subject was awarded additional common learning objectives related to programming, construction and technological analysis and use studies. However, these appear to be a limited share of the overall the Danish objectives regarding technology comprehension since empowerment of citizenship is an integrated part of the common learning objectives for visual arts. Discussing the relations between computational thinking and visual arts practices, Buhl (2019) argued that these two perspectives contribute to each other's domain of knowledge. Informed by perspectives on visual culture and contemporary art (e.g. Mirzoeff, 2013), the overall goal for visual arts in schooling is to facilitate transformational learning in which a global and participatory approach to art-making is prominent (Danish Ministry of Education, 2019a). Buhl (2019, p. 127) argued against

> *traditional and modernist ideas like visual production as an individualized and personalized expression, where the development of technical skills means manipulation of a medium, such as canvas, clay, or paint, or works of art are finished and fixed pieces that are produced in school.*

Instead, she suggested that a technology comprehension approach has the potential to go beyond digital applications that replicate analogue practices like painting (Buhl, 2019). From a contemporary art perspective, art-making is a design process that involves conceptual development and facilitates visual–social practices of meaning-making rather than the production of an artefact (e.g. Bishop 2006). Contemporary art practices offer the possibility to design for art experiences based on the principles of open-ended algorithms that invite one to not only use art but also to participate in art. Art has evolved from a practice driven by striving for the sublime to a practice in which the social and relational perspectives are prominent and societal engagement is promoted (e.g. Mirzoeff, 2013; Rogoff, 2008).

From a broader perspective, the school subject of visual arts, like other school subjects, emerged from basic domains of knowledge and/or practice. Thus, current developments in contemporary art and derived content will always affect the school subject. According to sociologist Niklas Luhmann (1995), visual art's societal function is to reveal the unseen, and the nature of art communication is to question what art is until it is hardly recognisable as art. Visual culturalist Irit Rogoff (1998) approached contemporary ideas of art appreciation as the experience of 'otherness' that simultaneously evokes curiosity and provokes critical reflection. Bringing contemporary visual arts into schooling is meant to engage students in social practices in which they explore contemporary art communication productively and receptively. This approach implies an explorative approach to the use of technological means for art projects that provide new thinking patterns and challenge modes of revealing the unseen. Thus, the focus in art practice is not on problem-solving, but on problem-setting without a demand of solving. From an educational perspective, this is crucial for promoting critical thinking. Schooling in different knowledge domains serves different functions in society, with the implication that the overall learning objective of technology comprehension will take different forms when integrated into existing school subjects. The Danish school subject of visual arts is a hybrid of art theory, art practice, art communication and art pedagogy, which form an ever-evolving basis for teaching. Since the 1980s, the subject has been intertwined with the evolution of digital technologies (Buhl, 2002, 2019). Contemporary art currents and new materialism theories suggest a third path that combines the path of technological logics and the path of social inquiry as integrated learning modes. This may be the rationale for the learning objectives chosen for the technology comprehension initiative in Danish visual arts education. Creating a hybrid of technology and visual arts to teach competences and civil empowerment served as the basis for development of six prototypes for teaching technology comprehension in school subject visual arts.

2.1 Learning objectives for technology comprehension in visual arts education

Common learning objectives for technology comprehension among 1st to 3rd graders were added to the common learning objectives for visual arts and include the following:

- *Programming and construction*: The student is capable of aesthetic expression via programmable technologies and has knowledge about simple programmable technology for pictorial production.

- *Technology analysis*: The student can name functionalities and describe relations between function and interfaces in digital artefacts from the field of arts and visual culture. The student has knowledge about function, interfaces and their relations in aesthetic contexts.
- *User studies*: the student can investigate the use of digital artefacts and technologies in exhibitions. The student has knowledge about simple techniques for investigating the use of digital artefacts and technologies in exhibition contexts and is able to communicate the results (Danish Ministry of Education, 2019a, 2019b).

3. Six prototypes for teaching technology comprehension in the visual arts

Visual arts education professionals working in elementary schools and teacher education programmes developed six prototypes for teaching technology comprehension in the visual arts. The prototypes are based on ideas inspired by pragmatism, in which meaning-making is negotiated through social practice and performed as an iterative process of inquiry (e.g. Dewey, 1979; Rasmussen, 2017). Furthermore, important aspects of Danish school subjects are critical thinking and citizenship (e.g. Freedmann, 2003; Tavin, 2015). General education was not included in visual arts in the national technology experiment; however, as a part of the existing visual arts education, this perspective contextualised the prototype activities, as evidenced by the thematic approaches to the activities. During the development process of the prototypes, the iterations were reviewed and quality-assured by a researcher in visual arts education focusing on the subject-specific knowledge domain and by a learning consultant representing the Danish Ministry of Education who was focused on the overall goal of the project. Additionally, representatives of the target group from the participating schools commented the prototypes. The prototype development followed a framework that was shared by all school subject prototypes and based on a pedagogical process model[1] The model divided the prototype activities into an intro phase, a challenge and construction phase and an outro phase. The six prototypes represented key learning areas in visual arts education, combining the school subject's learning objectives and the newly added technology comprehension learning objectives (see section 3.1). The next paragraphs summarise the six prototypes, the pedagogical ideas behind them, the chosen technologies and curriculum related learning objectives.

3.1 Pattern and shape

The Pattern and Shape prototype instructs students to develop their own visual patterns through analogue and digital processes. They will explore visual patterns from the perspectives of both the producer and recipient in order to understand the logics behind coding and constructing. The intention is to generate an understanding that patterns are both a visible visual expression in culture and nature and an invisible structure underlying digital artefacts. When a robot is used to produce pictures, students work both with the logics, construction and visual expression associated with patterns and get an understanding of the logics of computational thinking. More precisely, the students explore the question 'what is a pattern?' via a walk around the neighbourhood as well as discussions of the meaning of patterns as environmental markers, distinctions and variations. Next, students will construct analogue patterns by combining geometric coloured shapes and, afterwards, trying to decode the principles that are applied. To bridge analogue and digital programming, the students 'programme' each other to follow specific forms and routes and deciphered everyday gestures, like teeth brushing, in order to support embodied learning. A tactile, programmable robot—BeeBot or BlueBot—is introduced with an added marker. On large paper banners on the floor, the students playfully explore and experiment in iterative processes, reflecting on the pros and cons of using a robot to design patterns. In the final presentation the focus is on trying to figure out how a pattern is made, including the system and coding, and how it is visible.

3.2 Exploring colour

The Exploring Colour prototype, instruct students to explore and study colours, their environmental impact on atmosphere and their use for expression in visual art. They create colour blends and traces in both analogue and digital forms via randomised and controlled coding and construction. Rather than using classic colour blend schemes, this course encourages a playful and explorative attitude, supported by the robots, toward visual expression. The robots play an active role in the making of pictures, and analogue and technological expression and the underlying coding are intertwined in the image process. Overall, this course works towards the TechArt

[1] The model is explained on the homepage of the project: https://xn--tekforsget-6cb.dk/wp-content/uploads/2019/04/Format-og-vejledning-til-de-didaktiske-prototyper_april2019.pdf

concept. First, there is a dialogue about colours, their names, blends, nuances and so on, studying examples from art and visual culture. The students then go hunting for colours in the classroom, in their school bags and around the school, categorising and producing colour samples with crayons. The next step is to produce pictures using technology. First, students paint different backgrounds, focusing on colour rather than on figurative expression, and study the results, considering the chosen painting tool and paper texture. Then, the students are introduced to the Sphero Mini, a small ball-shaped robot capable of making random traces on paper. They can test out the visual results of different codes, several tactile wrappings on the Sphero and a variety of colours from their previous analogue experiments. Finally, the analogue backgrounds are merged with Sphero's movements through programming and coding. When analysing the final pictures, a specific language supports students' understanding of both visual and technological aspects.

3.3 Animated stories

In this prototype, the students are instructed to develop imaginative and playful animated visual stories using the programmable app Scratch Jr. To preview the analogue and digital processes in which they participate, the students explore and analyse samples of animated stories concerning aesthetic expression, visually decode the movements and changing positions of figures and new combinations and then explain them. This course supports the concept of TechArt by encouraging students to combine and integrate curious and critical approaches to animated visual story production as well as consider the conditions and possibilities of the used technology. While participating in this activity, which combines production and reception, the prototype lays the foundations for technological capacity and digital empowerment. The course starts with an introductory dialogue with the students about animations and cartoons in which temporality is framed as a visual category. In order to achieve a material experience with programming and construction before engaging in more abstract digital programming with Scratch Jr., the students make an analogue 'animation' with paper, cardboard figures and a script for three scenes, showing how the figures change position and move from frame to frame. The next step is testing the code blocks and drawing functions in Scratch Jr., experimenting with rearranging the coded orders and testing the visual consequences before creating the digital animation. In pairs, the students create a short story, design backgrounds, animate one figure at a time, test the visual relations and qualities and add a soundtrack. Finally, they arrange an exhibition with iPads, like an installation with which visitors could interact.

3.4 Pixelart - in art programmes

In this prototype, the students re-create an analogue photo as a digital artefact using an image editing software. The idea is to introduce digital images as data that are always changeable, which they experience when exploring and reflecting on different functionalities of the software. Furthermore, they are instructed to produce a flow diagram, which is a strong visual indicator of the underlying algorithms, which can be rather abstract. Through productive and analytic activities and dialogues about their image-making, the students' digital empowerment and technological capacity are gradually enhanced. As a result, the course supports TechArt.

The course starts with a dialogue about visual art and the differences between paintings, x-rays, movies, computer games and so on. Next, the students bring to class an analogue, paper photo that will play a central role in the pictorial work to come. The photo is digitised so that it can be transformed in the image editing software Paint through, for example, performing pixilation, changing colours and replacing pixels or pulling the photo. The students are introduced to the functionalities of Paint and asked to explore them in the picture transformation process. In parallel, every student makes a four-step flow diagram with screenshots to chronologically show changes throughout the process of transforming the original photo to the final manipulated version. This allows them to identify and reflect on the meaning of the digital manipulations. In the final exhibition, analytical focus is placed on aesthetic expression, the possibilities of digital versus analogue processes and the consequences of digital manipulation.

3.5 Nasubi Gallery

The Nasubi Gallery prototype instructs the students to explore possibilities for creating different types of visual expression, meanings and information using digitally manufactured light in an analogue, 3D tableau with a thematic content. The students are asked to experiment with and investigate the programming and construction of a micro:bit, which is a pocket-sized computer, to create meaningful light designs to interact with the tableau, not just as an additional element, but as an influencing factor and integrated part of the visual expression. What makes this a TechArt course is its contribution to both students' understanding of visual art and technology through thematic study of a phenomenon. Furthermore, by transforming an analogue 3D image into a digital generated image, the prototype has the potential to make students aware that impermanent visual and conceptual variability have implications on digital visuals.

The students examine 'tableau' as a visual category and light's role concerning atmosphere, substance and visual expression while discussing samples. An introductory exercise in which students construct simple model-tableaus and make analogue light experiments with a flashlight provided ideas about the interaction between analogue and digital approaches and about light as a marker of change. They also get the opportunity to explore the micro:bit using different code blocks inspired by tutorials and collaboration. Finally, they create an analogue tableau and use a micro:bit to generate light corresponding to the thematic perspective of the tableau and reflect on the implications and possibilities of working with both analogue and digital processes. During the course, they will explore different outcomes of programming and coding by hacking a given code, rearranging the order of the code and explaining the outcome.

3.6 3D Sculpture

In the 3D Sculpture prototype, the students are instructed to design digital artefacts in a 3D modelling program using programming and code blocks to construct a sculptural form. They will explore the functionalities of the program but focus on the visual art perspective, working with volume, scale and repetition. This course is a TechArt course as visual art and technology are intertwined in the creation process and product. The 3D modelling program has the potential to expand students' understanding of 3D forms as it offers new possibilities for designing sculptures using different principles for construction than are used in analogue processes. The students has to consider whether the combination of code blocks support their visual intentions, which supports digital empowerment and technological capacity.

At first, the students can go on an excursion to see sculptures for inspiration and examine their shape, material, assembly, size, colour, spatiality and aesthetic expression. Drawing upon their experiences with, for example, Minecraft, the students can explore the 3D program Tinkercad and experiment with different code block combinations to see their effect on the output (i.e. the sculpture). By adopting both a productive and receptive position and by sharing experiences with each other, the students will enhance their ability to reflect on the benefits and disadvantages of using this digital technology to design a sculpture. They may also try to identify how certain sculptural forms are generated by specific code blocks. To support these abilities, there is a focus on using specific language to enhance visual and technological comprehension.

3.7 The progression of a TechArt learning process

The six prototypes will be tested in the schools in the next phase of the project. From an analytical point of view, they facilitate a progressive TechArt learning process. The first two prototypes focus on a basic introduction to the epistemology of programming and construction and the components of computational thinking. These new thinking patterns are investigated through students' tactile and embodied visual actions, which facilitate step-by-step experiences with the logic of creating algorithms and data processes. The TechArt learning outcome of activities indicates deeper comprehension of the principles of order, which may be recognised as patterns, shapes, lines and rhythms in physical surroundings, such as architecture, that serve as visual markers in two- and three-dimensional images. Furthermore, the students have their first encounter with image-making as a concept-driven process based on a set of instructions for action rather than the creation of a fixed product for appreciation by an audience. The computer logic and art logic of 'how to' concretely merge (Sack, 2019). By studying the colour traces created by a robot, the students examine laws of causation, actions, outcomes and, thereby, the relation between programming for randomness versus intentionality as a principle for contemporary art-making. They come to understand coding as a displacement of colouring, a manual action performed with a brush, and, through this displacement, reveal the core of conceptual art-making.

The next two prototypes explore the complexity of how programming and construction invisibly work to regulate and steer visual processes. The creation of animated stories and use of image processing continue students' investigation of the logics of programming and construction, but with a focus on the societal implications and, thereby, the type of critical thinking promoted by visual culture studies (e.g. Mirzoeff, 2013). The TechArt learning outcome of the activities facilitates students' first attempt to analytically understand the extent to which technology is entangled with human actions, including in the digital artefacts that are part of students' everyday lives (Barad, 2008). The hands-on process of creating an animation stimulates students' curiosity and interest in creating stories. Performing visual analysis through experiments with digital images as materials increases students' awareness of digital image-making as always changeable and of images as manipulatable constructions. The two prototypes provide students the opportunity to encounter what may be experienced later as possibilities to manipulate and distribute stories and images via artificial intelligence and beyond human control.

The last two prototypes integrate programming and construction in established activities from the curriculum: installation and sculpture. By programming of a micro:bit to add light to an analogue tableau, students explore a blend of digital and analogue materials as aesthetic means for expression. Moving the process of making a sculpture from an analogue environment to a digital one, and thereby changing the way in which materials are creatively processed, combines students' knowledge of displacement and the ability to always change digital materials, which they gained from the previous prototypes. It offers the possibility to use programming to create analogue 3D pieces, transform an analogue art form into a virtual process and create various types of products. These new modes for 3D production could be incorporated into changes to the school curriculum.

The TechArt learning outcome regarding analytical concepts like decomposition and recomposition is to provide new perspectives on the classical sculpture techniques of adding, carving or modelling analogue materials and to avoid a linear creation process governed by material qualities. The creation of the sculpture takes place ahead of its materialisation via programming and 2D testing. This means that manual mastery of a material is not required. From this perspective, the process can be seen as a transformation of subject-related competences, since manual aesthetic modelling skills are replaced with aesthetic coding skills, and there is no bodily contact with material (Sack, 2019). The sculpture produced by digital intervention is not a replacement of a known sculptural process, but a new image-making process. Technology creates a division between the hand, tool and material and introduces distance between bodily perceptions and the object, but it also involves a pattern of thought connected to programming skills. From a visual arts perspective, this may reinforce students' programming skills or it allow students who are more skilled in programming than art to express themselves visually. From the perspective of technology comprehension this may meet the overall learning objectives of *technological capacity building* (see section 1) and the subject specific learning objective of *programming and construction* (section 2.1)

Altogether, the prototypes show the prospects for development of the visual arts curriculum; technology could be seen not merely as a tool, but as a way to produce art. Each prototype involves art-making activities dealing with subject-specific learning content as well as logics related to programming and construction. They promote the development of curiosity and the ability to put activities into context. Furthermore, the prototypes reveal a rich, material-based perspective on the entanglement of human and non-human actions and thereby provide prospects for understanding and developing visual practices.

4. Conclusion

The six prototypes revealed that encounters that involve both art practices and digital programming and construction generated new pictorial language and visual expressions and, thereby, the potential for other modes of meaning-making. The programming and construction can, to some extent, be compared with contemporary art practices that are characterised by 'programming' when artists create concepts. These concepts are realised when an audience or a group of participants are activated by creating a relational aesthetic encounter and realise the concept. The examination in this paper has mainly focused on common learning objectives connected to visual arts as a school subject. This is partly due to the focus is defined by the national experiment on technology comprehension. From this point of view, the six prototypes have the potential to influence the development of the school curriculum. Successful integration of technology comprehension in visual arts education requires teachers to have competence in both contemporary visual arts and technology, which is a demanding combination. A technology comprehension integration in visual arts must be driven by and based on a contemporary school subject, with a profound understanding of the purpose of visual arts and of technology in school. Otherwise, both subjects will serve other agendas than to prepare children to be participants in their present and future lives. When performed with pedagogical professionalism, we argue that art-making can integrate technology comprehension and provide relevant TechArt learning.

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