Digital 3D modelling as an expansion of the aesthetic repertoire for image-making practices.

Concluding discussion

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Foreword

The following 3D Digital Modelling in Visual Arts Education forms part of the Tilde series and is based on collaboration in a project involving Aalborg University and College University Copenhagen (Denmark), the University of Gothenburg and Umeå University (Sweden). The project's aim was to explore the learning potential held by 3D sculpting for art teachers by identifying new image-making processes in modelling and sculpting. Another aim was to integrate the project's outcome in didactics and teaching activities for teacher educators in visual arts connected to the subject area.

The project was financed by EDDA Norden during 2021 and several seminars were arranged to present research in the subject area visual arts, 3D modelling, and use of technology. The results may be of particular interest to a wider audience in the research fields of visual arts education, multimodal learning designs, and teacher education. The publication is based on presentations made at Aalborg University in Copenhagen during the autumn of 2021 and at a symposium called 3D-sculpting: A Nordic Higher Education Collaboration Project at the NERA conference held in Oslo in the spring of 2023.

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Introduction

Mie Buhl & Tarja Karlsson Häikiö

The latest developments with artificial intelligence (AI) – generative AI – are facilitating new ways of working with image-making. Manovich (2023) describes the development of generative AI as being so radical that it can be compared with the invention of photography in the 19th century or the introduction of linear perspective in Western art during the 16th century. The recent developments once again provide visual arts education with both new opportunities and fresh challenges. A big challenge is how to teach image-making using a computer. According to Manovich, "prediction" is the new term for computers translating information into works of art. He believes that translation between media such as books to film is not a new phenomenon. Still, the use of a computer as a translator based on binary coding is different and calls for art-making skills entailing a mix of ideation, coding, and programming skills. It is different from the traditional ways images have been produced. His ideas about computer-generated images match the thinking underlying the basis for the project 3D modelling in visual arts education. Here, we were interested in exploring which image-making skills are required for computer-generated 3D modelling. The process lacks a tactile connection with the actual artefact. The process of generating a code for a computer to process 3D models on a screen and for printing has been a possibility for some time.

The transformation of the sculptor from a performer with, e.g. clay, to someone who trains computers to process data for new 3D images, or simply asks the computer to produce a 3D model, is naturally altering the perception of what it means to make visual art and who makes such art.

In a teaching context, an important question concerns what should be taught in the visual arts and how the increasing digital entanglement in all practices should be handled in the various disciplines of the teaching subject.

Between 2020 and 2022, an EDDA Norden-financed development and research project, *3D Digital Modelling in Visual Arts Education*, was launched to explore digital 3D modelling. The project was organised as a collaboration among several Nordic universities and partners.[1] The project participants came from several countries – Denmark, Finland, Iceland, Lithuania, Sweden – with a total of 19 people being involved in the project activities.

The project was primarily linked to art teacher education in the partner institutions, with a second focus given to teaching visual arts in primary and secondary schools. The project aimed to explore the learning potential held by 3D sculpting for art teachers. Another aim for the participants was to integrate the project's outcomes in higher art education; more specifically, the didactic teaching and planning activities to do with teacher education in visual arts at the participating teacher education institutions.

Digital 3D modelling was chosen because it gives the opportunity to experiment with different interfaces between digital and analogue materialities and explore a range of formats of space, place and scale. 3D modelling – in the form of sculpture – is part of the curriculum in both Denmark and Sweden and, along with painting and drawing, has a constitutive function in visual arts education as part of general education in schools and as a subject area of expertise in teacher education. A research interest shared by the participants was to address:

- How can the subject matter visual arts balance between the expressive aims in art-making practices and the skills needed to use programming and technologies?

- Which are the educational implications of the use of programming and 3D printing for art-making practices in matters of aesthetic qualities, didactics, teaching competencies and challenges of 'subject-matter-DNA'?

- Which opportunities 'to break new grounds' in the teaching discipline of visual arts are emerging from engaging with programming and 3D printing?

HYBRID ORGANISATION OF THE PROJECT

The project was designed by drawing on insights from design-based research (Amiel & Reeves, 2008) and organised as a developing project. At the outset, scholars from the participating institutions together explored digital 3D modelling in workshops. The form taken involved a combination of online instructions, offline activities and online discussion forums on whose basis the project partners developed subprojects and tested learning designs at their own universities that shared and related the results to the overall theme. The learning designs that were developed revolved around improving image-making competency within sculpting and 3D technology using photogrammetry and TinkerCad for visual arts education. The research questions of the subprojects

1 Aalborg University in Copenhagen, College University Copenhagen (Institut for Læreruddannelse, Campus Carlsberg at Københavns Professionshøjskole) in Denmark as well as Umeå University and HDK-Valand at Gothenburg University in Sweden. The planning/project group: Mie Buhl, Aalborg University; Kirsten Skov, University College Copenhagen; Dan Tommi Hildén, HDK-Valand; Tarja Karlsson Häikiö, HDK-Valand; Frida Marklund, Umeå University; and Mikael Heinonen, Umeå University.

were guided by one of two questions:

- How does the process of creation, starting with the creation of a sculpture by way of analogue manual mastery of a material, transform into a digital format?

- How does the linear creation process, governed by material qualities, take new directions when the creation of the sculpture takes place via programming and 2D testing?

Activities in the project aimed to overcome the typical focus on the technological implications of the 3D practices and to instead study the sculptural qualities while using the technology artistically as well as looking at the didactic implementation in higher education. The hands-on themes of the project activities built on the idea of modelling 3D forms by applying principles different from analogue designing methods as a new image-making process relying on other ways to sculpture and to understand material. The idea was to curiously and critically explore the possibilities provided by the technology when used in a visual arts context. The hands-on activities were based on analogue and traditional art-based making (modelling clay, sculpting) transformed into a virtual form through photogrammetry and the use of a digital CAD-program, where the relationship between matter, the intangible, and perception was focused on in the translations between materiality, immateriality and back to material again.

The project has contributed to greater knowledge about visual 3D modelling, photogrammetry and the use of TinkerCad among teacher educators in visual arts and stimulated 3D projects in the school subject visual arts as a platform for developing visual competency, modelling and sculpting. The project activities have helped to overcome the focus on the technological implications held by 3D practices and instead inspired the study of sculptural qualities that arise while using the technology artistically as well as a consideration of the related didactic implementation. For instance, the project has created an understanding of scale in the digital domain for student teachers in visual arts through working with everyday objects and using artistic tools. It has contributed to both the discussion between the participating higher art education institutions about how digital technology adds new tools for visual arts production and to the sharing of experiences with respect to didactics. In this way, the project has assisted in gathering arguments for visual arts education as highlighted by research on visual culture and the development of visual competency as a civic right and a wider context concerning medialisation in society aiming at designing for teacher education in the visual arts.

The outcomes of the development and research project feed into a Nordic discussion to do with how digital technology not only provides new tools for visual arts production but may transform the existing modes of visual expression and sensitive cognition. In this edition of the Tilde series, *3D Digital Modelling in Visual Arts Education*, three of the participating sub-projects are presented along with an article about the Danish artist Morten Modin, who inspired the project with his artwork and by offering expertise through his participation in a seminar attended by the researchers. The articles are hopefully relevant for the further development of the paradigmatic basis for subject didactics and the professionalisation of future visual arts teachers.

The first article is written by Mikael Heinonen and Frida Marklund. Entitled "*3D sculpting in digital and analogue domains: Transformations as a learning process*", the article is based on workshops with second-year student teachers in visual arts at a university in Sweden. In these workshops, the student teachers relate to and deal with transformations while moving between digital and analogue domains when creating basic 3D objects in design workshops. The aim is to explore different affordances in digital and analogue techniques in a design process, especially regarding cooperation and the social aspects of learning. The student teachers select an everyday object (Norman, 1998) and translate this into a 3D model that is later printed using a 3D printer. The learning process includes problem-solving as well as dealing with materiality and scale in between the use of digital and analogue techniques in the workshops. The student teachers discuss and compare interpretations, differences and similarities in groups based on their experiences from the digital and analogue workshops. The results show that previous experience is a factor in understanding a creative process and how perceptions and material, together with problem-solving strategies, inform the learning processes of the student teachers. The results of the explorations are analysed and discussed based on pedagogical insights from the workshops where thoughts on experience, doing and undergoing are connected to Dewey (2005) and Schön (2003), namely reflection-in-action and social aspects of learning.

Written by Dan Tommi Hildén and Tarja Karlsson Häikiö, the second article entitled *"Sculpting, photogrammetry and computer-aided design (CAD) in primary teacher education"* is based on a study of virtual lessons with primary student teachers taking a professionalisation course at a university in Sweden. The primary student teachers were to enhance their didactic skills by creating an understanding of photogrammetry and using the digital program TinkerCad. The assignment to these students is based on *double didactics* (Hildén, Karlsson Häikiö & Nordström Graf, 2024), or thinking about how they can use 3D and TinkerCad with pupils in primary school at the same time as they are learning the process themselves. In the lesson, the primary student teachers train in the making of a visualisation of an everyday object in the digital program after drawing and sculpting the object in clay and writing about their process in a blog. Once they have transformed the analogue object into a virtual ditto, they learn how to use the program to shape the object virtually. The study results reveal how materials through 3D sculpting work as a mediator of artistic quality and individual expression and how didactic reflections on teaching pupils are evoked in the learning situation with the primary student teachers.

The third article, *"From 'tool' to 'collaborator': Digital 3D modelling as a catalyst for new aesthetic practices. A study of student teachers' education in visual arts"*, is written by Mie Buhl and Kirsten Skov. The article discusses how digital coding and construction may change the didactics in art-making practices in visual arts education. The article is based on a study of 3D modelling practices by student teachers in visual arts at a university college in Denmark. In this text, we can follow college students learning processes using TinkerCad and GIMP, a free open-source photo editor, as tools to transform public spaces. The assignment for the college students is to create a visual and virtual manipulation of a site-specific public space by designing a prototype in the 3D modelling program. The theoretical framework concerns art-making as a social and material practice with digital technology as a co-productive partner (Fenwick & Landri, 2012; Knochel, 2016a, b). The discussion draws on the concept *hybrid assemblages* to describe how learning emerges from a continuous social practice of materialities of 'doing', to which meaning is attributed (Fenwick & Landri, 2012). Buhl and Skov (Buhl, 2019; Buhl & Skov, 2021) describe programming as a mode of concept art and as a paradigm clash between art-making practices and coding practices. The results show that the college students use different solutions and site-specific artefacts integrating into, enhancing and challenging the surroundings. The article presents a discussion on programming as a mode of concept art and the paradigm clash between art-making practices and coding practices and how different subject conceptions enable, yet also clash, in this kind of learning processes while using analogue and digital media (Buhl, 2019).

The fourth article, *"'Wrestling' with 3D printers, searching for materiality – Morten Modin"*, by Mie Buhl and Kirsten Skov presents the artistic work of the Danish artist Morten Modin. The contribution is based on a presentation and conversations with him during the 3D project together with his own written material. Modin has used digital technology and 3D scanning in his art works and thereby created both giant and smaller sculptures that are innovative in their performance yet also contain thought-provoking themes. The text discusses his site-specific artwork *The Unwanted* (Da. *De uønskede, Morten Modin,* Broch-Lips, 2021), located at Kongegården in Korsør, which is a set of sculptures where he processes and challenges historical narratives. Moreover, other exhibitions and art works by Modin are presented out of several exhibitions of his art works. Based on his works, Buhl and Skov discuss the possibilities and problems with art works that are digitally produced and how the imperfectness of digital traces in sculpting forms part of a unique expression.

The final text, *"Digital 3D modelling as an expansion of the aesthetic repertoire for image-making practices. Concluding discussion"*, is written by the editors. In this contribution, Buhl and Karlsson Häikiö reflect on the results of the project where 3D and sculpting occupy the centre of attention. They reflect on the didactic possibilities afforded by the use of CAD programs and 3D scanning, sculpting and printing, yet also the challenges that arise when manual and haptic modelling skills turn into coding skills when the modelling is digitally produced. Which skills are developed or needed to understand the transformation from manual to digital? This transformation is discussed from societal, cognitive and technological perspectives and with regard to visual arts education. What happens when digital technology enters teaching?

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Mie Buhl & Tarja Karlsson Häikiö

REFERENCES:

Amiel, T., & Reeves, T. C. (2008). Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda. *Educational Technology & Society 11*(4), 29-40.

Buhl, M. (2019). "Computational thinking utilizing visual arts, or maybe the other way around." In Ørngreen, R., Buhl, M., & Meyer, B. (Eds.), *Proceedings of the 18th European conference on e-learning,* (p. 102–108). Academic Conferences and Publishing International.

Buhl, M., & Skov, K. (2020). Making Collaborative Place Manipulations. In Cloutier, G., Ding, P., Kukkonen, T., Shields, A., & Sokolowski, J. (Eds.), *Making I Proceedings* (p. 159-164). Viseu: InSEA Publications.

Buhl, M., & Skov, K. (2021). "Har I robotter til at male for jer?": Et fagdidaktisk perspektiv på teknologiforståelses fagfornyende potentiale i billedkunst [Do you have robots to paint for you?": A subject didactic perspective on the subject-renewing potential of technological understanding in visual arts]. *Learning Tech – Tidsskrift for læremidler, didaktik og teknologi*, *10*, 382-404. https://doi.org/https://learningtech.laeremiddel.dk/laes-learning-tech/learning-tech-10/har-i-robotter-til-at-male-for-jer/

Davies, M. (2012). *Graphic design theory*. London: Thames & Hudson.

Dewey, J. (2005). *Art as experience* (Perigree trade paperback ed.). New York: Penguin books.

Fenwick, T., & Landri, P. (2012). Materialities, textures and pedagogies: socio-material assemblages in education. *Pedagogy, Culture & Society, 20*(1), DOI:10.1080/14681366.2012.649421

Hildén, D., Karlsson Häikiö, T., & Nordström Graf, R. (2024). Förtrogen med bild - Visuellt kunniga lärare [Familiar with images - Visually literate teachers]. In Forsler, I., Magnusson, L. O., & Öhman, E. L. (Red.), *Bild och visuell kultur. Undersökande bildundervisning i grundskola och fritidshem.* [Visual arts and visual culture. Investigative teaching in visual arts in primary school and after-school care]. Lund: Studentlitteratur.

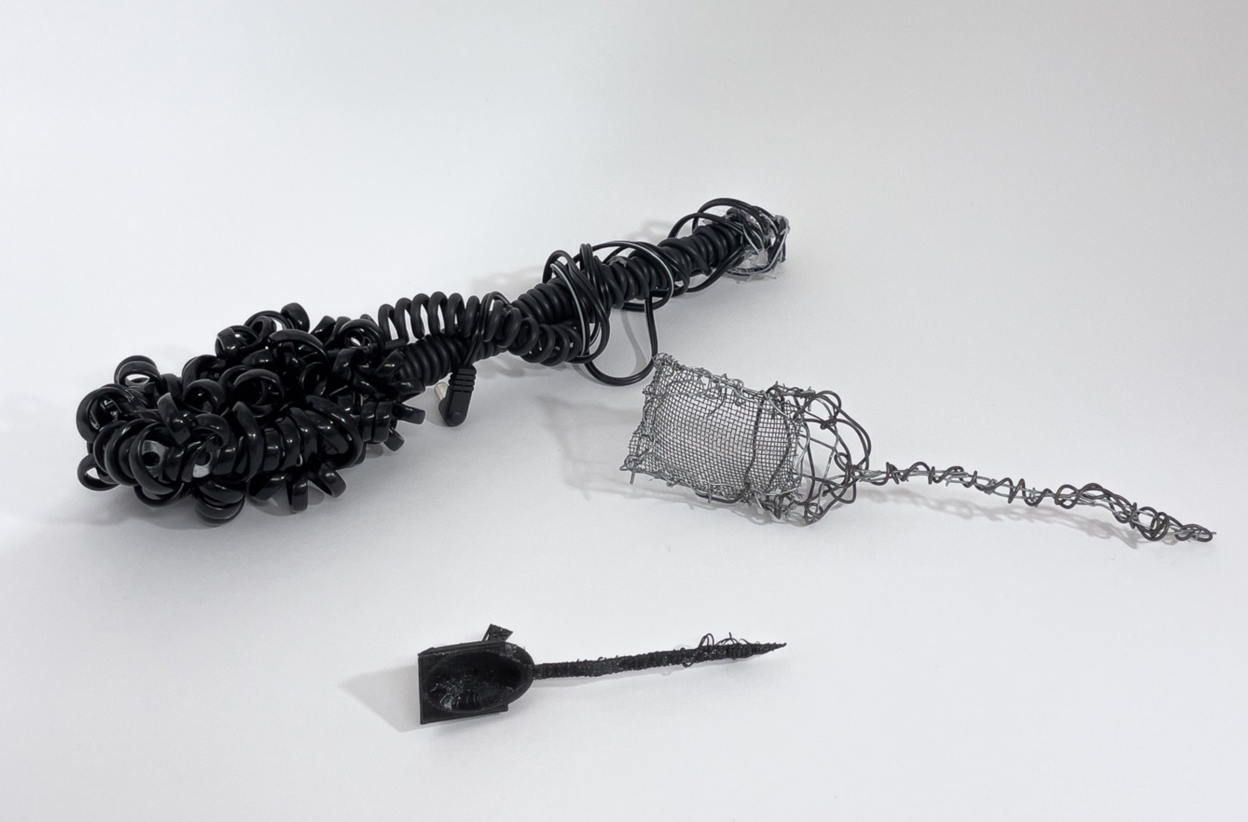
Knochel, A. D. (2016a). DIY Prosthetics: Digital Fabrication and Participatory Culture. *Art Education, 69*(5. DOI:10.1080/00043125.2016.1201401

Knochel, A. D. (2016b). Photoshop teaches with(out) you: Actant agencies and non-human pedagogy. *Visual Arts Research,* 42(1). DOI:10.5406/visuartsrese.42.1.0071

Manovich, L. (2023). *Artificial Aesthetics: A Critical Guide to AI in Art, Media and Design,* http://manovich.net/index.php/projects/artificial-aesthetics-book

Norman, D. A. (1998). *The design of everyday things* (New ed.). London: MIT.

Schön, D. (2003). *The reflective practitioner: how professionals think in action* (Repr.). Ashgate.



3D sculpting in digital and analogue domains – Transformations as a learning process

Mikael Heinonen & Frida Marklund

INTRODUCTION

Visual culture and art making are today permeated with digital imageries and digital technology. Nevertheless, visual arts education – although strongly linked to contemporary art, film and media – has a more complicated relationship with digital technologies. This may seem paradoxical given that teachers in visual arts in Sweden have for a long time embraced digital technologies and also digitally produced pictures as part of the visual arts subject and its methods. On the other hand, digital technologies and materials have also challenged visual arts teachers. According to the latest national evaluation of visual arts education in compulsory school (Swedish National Agency for Education [SNAE], 2015), one explanation is the lack of knowledge due to insufficient opportunities for further training among teachers, but also due to the inadequate funding of schools to equip art classrooms with up-to-date software and hardware. Another consideration is that digitalisation is challenging epistemologies within the subject, such as values regarding authenticity and the importance of hand-made pictures prepared using traditional techniques (Marner

& Örtegren, 2013). However, such values are not stable and probably vary among different teachers depending on their experiences and interests. Klein (2021, p. 28) describes today's digital technologies as being interwoven with "social, cultural, political and also geographical environments to such an extent that it results in new cultural, symbolic, and material forms". Art educators are living and working in the midst of this social and cultural change. Knowledge and learning in a digitalised world are recognised as a priority area by the Swedish Research Council (2023), and research in educational sciences is described as essential to meet the challenges that characterise schools and higher education, including the digitalisation of society.

This article presents the results of 3D design workshops conducted with student teachers in a Teacher Education programme leading towards visual arts in Sweden. The learning design workshops formed part of a larger development project called "3D sculpting: A Nordic higher education collaboration project" in which different universities with visual arts education programmes participated and explored aspects of digital technology in relation to visual arts education. The rapid pace of digitalisation in both society and within the visual arts subject itself raises questions about the use of different techniques and technologies in art-making relative to subject traditions, materiality, and sensory experiences in visual arts. The development project thus wanted to discuss the future implications for visual arts education when introducing new ways of doing, new ways of thinking and processing visual materials, from different perspectives and levels in the education system.

In the development project, each participating university was asked to conduct learning design workshops with student teachers, with different research questions based on phenomena of interest, the context or some delimitation. Since Umeå University offers Teacher Education programmes for visual arts in secondary and upper secondary school, this article has two main focuses: it highlights issues of relevance for teaching on those levels, together with teaching in higher education in order to prepare students to teach visual arts. The subject content and methods employed in the Teacher Education programme were intended to deepen students' understanding of subject-specific characteristics and also inspire their own method of development. With this in mind, these 3D design workshops examined how student teachers in a Teacher Education programme leading towards visual arts related to and dealt with different transformations while moving between digital and analogue domains when creating 3D objects. By studying what appeared to be easy or difficult for the students in each respective domain, how they cooperated and what was emphasised in the creative process, this article provides an empirical example of how groups and individuals deal with the various affordances in digital and analogue techniques. The aim is to explore the didactic potential of moving between digital and analogue domains in a learning process in visual arts education. What are the unique affordances of digital and analogue techniques in sculpting, and how do they impact student learning?

DIGITALISATION IN ARTS EDUCATION

Visual arts education in Sweden early on adapted new media and digital technology. The change of name for the school subject from "Drawing" [Sw. *Teckning*] to "Visual Arts" [Sw. *Bild*] in 1980 denoted the already ongoing broadening of the subject content and focus (Åsén, 2006). Since then, the subject has been moving away from defining images as chiefly aesthetic artefacts towards an understanding of images as part of visual culture and wider and more complex practices of looking (Lindgren, 2008). However, studies on the implementation of new digital technologies in schools show that they can challenge the traditional core of school subjects, causing a disruption of power between and within subjects (Erixon, 2014). Epistemological shifts due to digitalisation are also stressed in international studies. Two recent publications, *Post-Digital, Post-Internet, Art and Education: The Future is All-Over* (Tavin et al., 2021), which discusses art education with respect to Internet practices and its users, and *Global Media Arts Education* (Knochel & Sahara, 2023) that maps and presents various perspectives of media arts in education, both point to the need for further studies to explore and problematise the constant changing reality of visual arts education in relation to digitalisation.

In Sweden, several studies have examined the implementation of digital technologies in visual arts education. Björck (2014) showed how art work with computers can accentuate a technical discourse in the subject, shifting the focus from communicative and aesthetic qualities in images towards practical problems like how to use certain functions or tools to produce pictures. The national evaluation (SNAE, 2015) studied, among other aspects, frame factors concerning digitalisation such as access to equipment and further education among teachers, yet also how students relate to, understand and produce digital images in visual arts education. Marner and Örtegren (2013) described four possible approaches to digitalisation among teachers in visual arts: a) resistance; b) add-on; c) embeddedness; and d) digital media as dominant. However, the last category was not detected in their study. The authors explain that some teachers' resistance to digitalisation in visual arts education may have its roots in a fear of losing what they perceive as a core in the subject – its connection to materials, tactile knowledge, and working with traditional artisan techniques. Similar concerns are raised in a recent study on crafts education, pointing to the difficulty of learning embodied actions with ICT (information and communication technology) alone (Porko-Hudd & Hartvik, 2021). At the same time, several studies with an interest in media education and visual culture stress how popular culture, contemporary art, digital artwork and media can invite and engage students to participate and renegotiate notions of knowledge, identities and culture (Forsler, 2020; Hellman, 2017; Lind, 2010). Studies on 3D modelling and embodied experiences in visual arts are nonetheless scarce, probably due to the general emphasis on visuality in the subject, rather than three-dimensional artwork. A Nordic collaboration project such as the one described in this article thus contributes to the field, albeit each separate project is small in scale.

THEORETICAL POINT OF DEPARTURE

In order to analyse and discuss insights arising from the workshops, concepts from media theories as well as educational theories were used. From a multimodal perspective, different *modalities* (such as images, sound, words etc.) each have specific *modal affordances* (Kress, 2010). Kress defines modal affordances as the potentialities and constraints of different modes. This refers to what is possible to express and represent or communicate easily with the resources of a mode, and what is less straightforward or even impossible. According to Kress (2010), this is subject to constant negotiation for meaning-makers. From this perspective, the term *affordance* is not a matter of perception, but relates to the materially, culturally, socially and historically developed ways in which meaning is made with particular semiotic resources. In arts education, the term *media specific* is also used to describe a similar idea; namely, the specific affordances that each material and technique extends to a given medium. Hence, each medium has certain qualities, limitations and possibilities. Sculpting in clay, for example, differs from creating a shape in a digital 3D program because the latter is viewed and experienced on a 2D screen whereas the sculpting materials lack physical properties. These concepts thus allow us to look at how the students approached the tasks in the workshops with respect to their perceived scope for action in each respective domain.

With the understanding that digital technology, in line with Kleins' (2021) reasoning, is entangled in complex ways with social, historical and cultural contexts, students' use of digital technology cannot simply be seen as a technical act of communication – it is also an embodied experience of meaning-making. Dewey (2005) and Schön (2003) offer conceptional tools regarding experience and the social aspects of learning. Dewey's concept of *doing* refers to an individual's active engagement in the process of creating or making, while the concept *undergoing* refers to the receptive aspect of the experience, such as being receptive to the materials, tools and processes used in the act of creating. In Dewey's view, doing and undergoing are intertwined and mutually dependent, with each informing and shaping the other. There must be a balance between doing and undergoing for the experience to have the kind of transformative properties needed for learning to occur.

Schön's concept of *Reflection-in-Action* refers to the ongoing process of reflecting on one's actions and experiences as they are happening in order to adjust and refine one's approach in real-time. It may be viewed as a form of implicit or tacit knowledge used in the moment. *Reflection-on-Action*, in contrast, refers to retrospective analysis of an experience or action in order to gain insight and learning from it after the fact. While Dewey sees doing and undergoing as intertwined, Schön's Reflection-in Action is specifically focused on the active engagement of the individual in the process of making, as in engaging in a dialogue with the material at hand. Reflection-on-Action in comparison emphasises the retrospective analysis of the action that has taken place. Connecting Dewey's and Schön's concepts offers a broader approach to analysing the learning situation in the workshops.

THE EMPIRICAL STUDY

Interested in exploring how student teachers deal with the different affordances in digital and analogue domains, the two workshops were designed with a view to examining 3D sculpting from both a digital and an analogue perspective. Participants were second-year student teachers attending a Teacher Education programme leading towards visual arts.

In one of the subject courses, there is a module about form and design that is well suited to exploring 3D modelling and sculpting. Nine student teachers participated during 2021, and six student teachers during 2022. Each workshop was 3 hours long, and the second workshop was carried out approximately 1 week after the first one. The idea with designing these workshops was to 'force' the student teachers to move between first a digital and then an analogue domain, while transforming an everyday object in both scale and materiality, and from screen to a physical object – thereby transforming the concept of form and function as well. The digital part of the workshop was not a continuation of previous analogue sketching/ideation (which is otherwise often the case in visual arts education), but instead the starting point for their problem-solving. Well aware that this could be challenging for the student teachers, even though they have some pre-understanding of sculpting from earlier courses, the idea was to explore which issues, insights and problems would arise while doing so.

A qualitative approach was used, inspired by visual ethnography, meaning that visual methods (photography) and visual material (collected artefacts) are an important part of data collection (Rose, 2023). Both researchers conducted the workshops in 2021, but Marklund mainly acted as an observer, taking photos of the process and produced artefacts, as well as field notes. Heinonen was responsible for the practical implementation and also taught some basic concepts in TinkerCad, a free, rudimentary web-based application for digital 3D modelling (www.tinkercad.com). In 2022, Heinonen conducted the workshops alone. Nevertheless, the design, analysis and reporting were shared equally.

The empirical material consists of observation notes and photographs from the workshops and the produced artefacts. Written reflections by student teachers concerning their thoughts on the activities, the design of the workshops, and insights from the assignment were also collected after the second workshop. While observing the student teachers, particular focus was given to which questions the student teachers were asking to us teacher educators, each other, or in dialogue with the material/object. There was also an interest in studying what they highlighted as important in the creative process, as well as the significance of cooperation while solving an artistic assignment.

The workshops were a voluntary addition to the course – an opportunity for the student teachers to familiarise themselves with TinkerCad. The researchers were not teacher educators or examiners on this particular module in the course and the workshops were not graded. In line with the Swedish Research Council's ethical guidelines (Vetenskapsrådet, 2017), the student teachers received information beforehand about the development project and the study, their right to decline participation at any time, how the study manages personal data in accordance with the GDPR, as well as the possible publication of results arising from the workshops. Written consent was collected from the participants, which is stored safely and separately from the collected data. Two student teachers could only participate in one of the two workshops and were thus excluded from the study. The student teachers are given fictitious names in the article.

Image 1: Striations in a printed bottle.
Photo: Mikael Heinonen.

Workshop 1: Modelling everyday objects in TinkerCad

In the first workshop, the focus was on digital aspects of creating and exploring 3D objects. The student teachers worked in groups using TinkerCad to create 3D models of ordinary everyday objects. Each student teacher was asked to bring an everyday object to the workshop, but without knowing the purpose of the assignment. First, Heinonen gave a short introduction to some functions in TinkerCad. For example, how to navigate the 3D space in the app and how to add and subtract basic shapes from each other in order to create new shapes. The student teachers were then grouped into small teams. They had to decide within the group which of the everyday objects they had gathered to use for the assignment. They could only choose one object in each

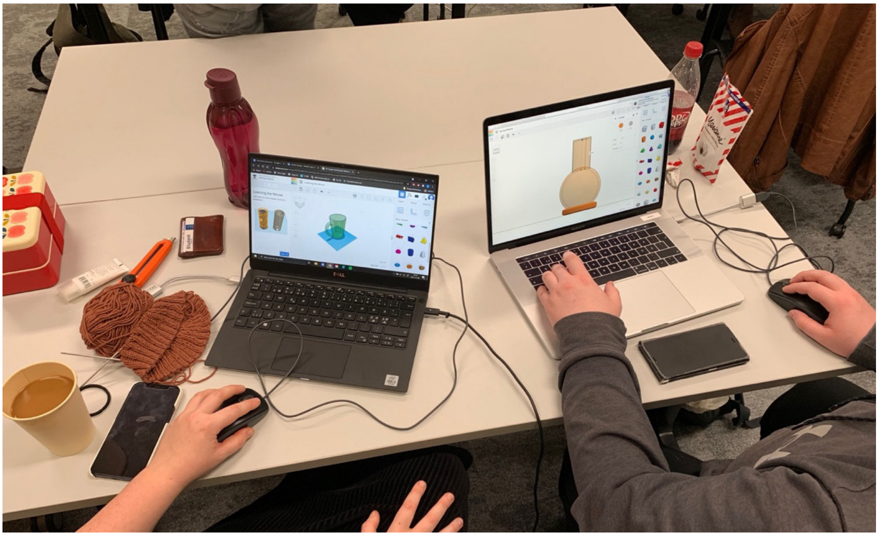


Image 2: Student teachers modelling and navigating 3D spaces in TinkerCad. Photo: Frida Marklund.

group. The teams were then tasked to translate the everyday object into a 3D model in TinkerCad. After the workshop, the different models were printed using a 3D printer.

Workshop 2: Transforming 3D prints to sculptures

The second workshop highlights analogue aspects of form and design. The task was first to individually transform the small, printed model they had designed in the previous workshop to a sculpture larger in scale, using a new material. They were also asked to accentuate something in the shape or expression that they found interesting, and they could also transform the function of the object.

The printed models looked different from the designs in TinkerCad, for example as a result of how the plastic material used by the printer creates striations in the surface of objects (Image 1). They could use different materials, such as modelling clay, cardboard, textile fabric etc. The purpose of the assignment was to highlight scale and proportions in sculpting, as well as material properties and physical restraints such as gravity and strength, which are emphasised when working with larger objects. Although in a digital setting this is not a problem, in analogue sculpting this becomes a factor the artist must consider.

Afterwards, the student teachers were once again grouped together and asked to compare and discuss their different interpretations and artifacts with each other in the group. What were the differences and similarities? They also wrote down group reflections about their experiences of sculpting in both a digital and an analogue setting. Did they discover something? What, in their opinion, are the possibilities or obstacles in each domain?

TRANSFORMATION AND TRANSDUCTION – EXPERIENCING MEDIA-SPECIFIC PROPERTIES

One observation from the first workshop was the way the student teachers approached the task of translating the everyday object into a 3D model. Instead of just trying or prototyping in an experimental

Image 3: Experiencing the physical restraints of the material properties. Photo: Frida Marklund.

way, the student teachers first attempted to intellectually solve how to recreate the shape of the everyday object. One interpretation is that this is a consequence of being unfamiliar with TinkerCad, but also a result of the design of the assignment in itself. Framing the task as chiefly the reconstruction of an existing object on one hand, and the affordances given by the digital program on the other, led the student teachers to strive for accurate reproductions.

Since materials in the digital domain lack physical properties and are processed on a two-dimensional surface (Image 2), which in itself is a media-specific characteristic, the material aspect that otherwise is so important in sculpting could not inform the student teachers' processes. In other words, in the digital domain the student teachers mostly did Reflection-on-Action (Schön, 2003) rather than Reflection-in-Action, meaning they identified problems that they had to correct through a retrospective analysis when they actually thought they were finished with the model, instead of intuitively reacting to the material aspects in the process. Some examples of this are how the students related to and experienced scale and proportions in the digital domain. They had some difficulties assessing how the proportions related to one another, and also how to navigate a 3D space on a 2D surface. In traditional sculpting, one constantly turns the artefact around or positions oneself differently in relation to the artefact to explore

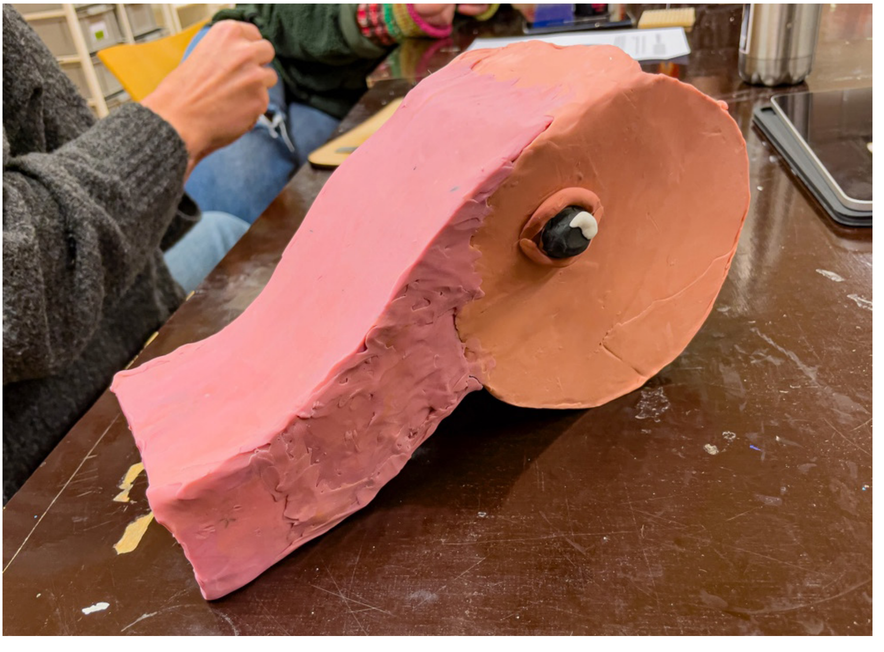


Image 4: A whistle transformed into an elephant. Photo: Frida Marklund.

its proportions for example (constituting Reflection-in-Action). Still, something as simple as that became difficult in the software, resulting in accidental displacement, an ear of a cup could be hanging in mid-air, or objects that should be in the same plane were not, which in turn meant the scale relationship was off. Understanding the basic principles in the software and how to export and save their models was nonetheless easy for the student teachers.

In the second workshop, when they moved over to the analogue domain, the student teachers discovered physical restraints. Now these properties, scale relationships and strength, for example, became emphasised. For example, one student teacher had some difficulties with the softness of the modelling clay which made the walls of the sculpture cave in (Image 3). This led to the student teacher abandoning the original idea and function of the object (a whistle) and instead exploring a new direction (an elephant) (Image 4).

When transforming their 3D printed objects into larger sculptures in a new material, the students remade the original objects' meaning through a new expression and materiality. This is the same as doing a *transduction* (Bezemer & Kress, 2008). Image 5 shows an example of different transductions of a printed object, but also how the print itself can inspire the student teachers to explore an independent expression in relation to the original object.

The group reflected on how their printed object had influenced their interpretations in the second workshop (Image 5):

> *The print had a fairly square design, but the printer produced some rather chaotic lines. We chose different design paths, without deciding it beforehand, in order explore different expressions. Anna's interpretation was deliberately angular, while Robins' object was a jumble of wire. (Group Blue)*

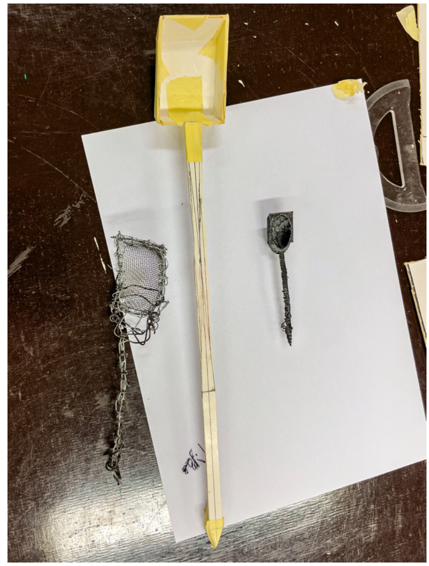


Image 5: A printed ladle transformed into new objects. Photo: Mikael Heinonen.

One result of these workshops is that a transduction occurs in the digital domain when moving from an analogue domain to a digital one (translating everyday objects to digital models). Then, when sculpting in an analogue domain, yet another transduction occurs. This means the student teachers are 'forced' by the workshops' design to experience different media-specific properties in a way that each respective domain might not have prompted in the same way, or as efficiently, by themselves.

DOING AND UNDERGOING – THE IMPORTANCE OF PREVIOUS EXPERIENCE IN A CREATIVE PROCESS

The importance of the student teachers' previous experiences and their emotional relationship with the process differed in the two workshops. Since digital tools generally are nowadays a natural part of life for this category of student teachers, the novelty aspect while using digital technology is somewhat diminished. There are expectations of what one can and cannot do with digital technology. At the same time, this particular software was new to most student teachers. Some student teachers therefore experienced irritation when their expectations were not fulfilled in their encounter with TinkerCad. They concentrated mostly on technical aspects of how and what to do, rather than using the tool to experience the object in a new way. Following the workshop, one student group reflected on this:

> *The digital has a learning curve, more focus on the technical rather than creative aspects. It doesn't feel 'manual' since you can revise it in a different way than what is possible in analogue sculpting. Digital work feels more results-oriented and analogue is more process-oriented. (Group Red)*

Here, Dewey's concepts of doing and undergoing can offer a way for visualising the difference in the students' experiences at work. Davis (2012, p. 219) explains this phenomenon, referring to Dewey as follows: "an experience has a pattern and a structure of alternating between doing and undergoing. 'Doing' is the physical or sensory interaction with our environment that we associate with the experience, while 'undergoing' is the mental reflection or emotion necessary to interpret the doing – an action and a consequence linked in perception". She draws a comparison with river rafting: In doing, we paddle furiously in parts of the whitewater trip, but the undergoing lies in having been challenged by the river and having won. For Dewey (2005), this relationship is what gives the experience its meaning. What makes something memorable depends on the content and scope of the relationship between these two concepts and our previous experience. Namely, what was visible in workshop 1 was mostly doing among the student teachers, unlike in workshop 2 (the analogue workshop) where their previous experiences of materials and forms evoked memories and stories and their prior knowledge could be used and combined in new ways in their work. One student group described the difference between the two workshops as the first one leading to reproduction, "we wanted to reproduce the original object more faithfully", while the second workshop offered greater freedom, which in turn led to "a looser expression, freer sculpting" (Group Blue).

Group Red referred to the analogue workshop as "more intuitive, although it's difficult to produce exact details like a 3D printer does". This difference in affordance between a digital tool compared to analogue techniques was identified by several groups. One group described how their object was simplified in the second workshop, yet also varied in its expression compared to the printed object: "The abstraction is visible in different ways in our interpretations; one is wilder than the other" (Group Yellow). Group Purple also discussed the first workshop. They found TinkerCad to be rigid and lacking in its toolset. They likened it to building a roof in The Sims (https://en.wikipedia.org/wiki/The_Sims_(video_game)), but found the game to be more advanced, "It could have been more fun to do it individually than to work in a group digitally, anyone not holding the mouse is easily excluded" (Group Purple).

This does not mean that the digital domain does not offer the possibility of undergoing, but the student teachers lacking skill in the software meant that most student teachers focused on solving technical problems at the first workshop, thus emphasising a more technical discourse in line with the results of Björk's (2015) study. However, the second workshop also made the student teachers reflect and draw insights concerning their digital work and thus both domains – the digital and the analogue – informed each other. It can namely be fruitful to oscillate between them in order to make comparisons or to simply experience different modal affordances in order to facilitate Reflection-on-Action (Schön, 2003).

PROBLEM-SOLVING WITH NEW TECHNOLOGY – DIFFERENT STRATEGIES

Another result that more concerns the social aspects of learning is the problem-solving strategies the student teachers employed in the first workshop. This theme can guide the reflection on teaching the subject matter at hand in visual arts education. What can be learned from workshops like these, and what does that say about how student teachers interact with new technology?

When facing the design task, the groups had different motives for dividing the work between them. Some became results-oriented, while others stressed the learning aspects more than the final product. One group, for example, was keen to distribute the work evenly between them. When one student teacher in the group started working on an object on his own computer, two other members in the group asked him to participate. Mary said: "You're going to be a teacher, you won't learn if you only (smiles) do that one (points at his computer screen). You can finish that one in your own time" (Group Green). Another group was proud to finish the task quickly. They simplified the shape, excluding complicated design features and when asked if they wanted to add some of the missing details, they replied that they were happy with the design as it was: "We want to save and export it now" (Group Purple).

Three strategies used by student teachers were identified:

1. *Detail oriented/high control & role distribution*: wants to ensure that it is exactly like the original object, aesthetic properties are emphasised, one person in the group controls the computer, while the others contribute with comments (are less active), it is the technically skilled student teacher who mainly controls the process.

2. *Focus on cooperative learning:* equal participation, 'everyone should be involved' is more important than the aesthetic expression of the object, learning within the group is central.

3. *"Good enough":* equal participation in quickly solving the task at hand, they simplify the form at the expense of its aesthetic expression, they take turns working with the software, they finish first and are proud of their form and show the other groups (function/solving the task takes precedence over expression).

Student teachers manage differently with the tasks, some prefer to finish fast, whereas others seem to be able to tolerate a higher degree of uncertainty in an experimental and creative process. Although this is probably not unique for digital art work but art work in general, one interpretation is that digital technologies can make these strategies more pronounced. This refers especially to the first strategy since digital technology can be used for high-precision recreations (a demanding technical skill). Research shows that many teachers in visual arts feel more confident using traditional materials and tools (Marner & Örtegren, 2013). As a consequence, a higher level of autonomy in the creative process was observed in the second workshop. One explanation could be that the student teachers worked individually, another that they related to the analogue process differently – there was a greater emotional connection to the materials and a better balance between doing and undergoing in their creative process.

CONCLUSIONS

The aim of this article was to explore the didactic potential of moving between digital and analogue domains in a learning process in visual arts education. Workshops with student teachers during their second year in the Teacher Education programme leading towards visual arts were used as an empirical example to answer the following research questions:

Which are the unique affordances of digital and analogue techniques in sculpting?
Materials and objects in the analogue domain have different affordances than in the digital one, which enable the student teachers to adjust their design goals relative to the material at hand. In the digital domain, the materials were in some respects seen as more limiting in what they can offer. The student teachers perceived them as having a more specific and delimited function. The expectations created by these perceptions can limit open-ended exploration in the process. The results show that the analogue sculpting also entailed technical challenges, but the student teachers' prior experiences made it easier for them to reflect in action and to improvise and solve, for example, challenges relating to gravity, proportions etc. This is of course also a result of this group of students, their pre-knowledge and expectations and the time limitation of the workshops. That said, the digital domain holds great potential to create situations for experiencing. However, the technical aspects can demand some time and attention for the users, which is something to consider in an educational setting.

How do these affordances impact student learning?
Student teachers approach and employ different strategies in the problem-solving situation. Some try to de-code the expected outcomes and to solve the task at hand as quickly and efficiently as possible, while others emphasise the qualities of problem-solving that the workshop provides. Yet another approach seen among the student teachers is to adopt a meta-perspective on the task itself and focus on learning aspects in relation to teaching – thereby highlighting democratic and collaborative methods in problem-solving.

The student teachers formulated some insights regarding the limits of gravity, the sense of scale between digital and analogue spaces, the importance of Reflection-in-Action, digital/analogue problem-solving, as well as the affordances and limitations when using/translating existing objects. The student teachers also reflected on their own future teaching practices, showing that workshops like these can form a good basis for further exercises and discussions within the Teacher Training programme.

DISCUSSION

One important aspect to consider with regard to visual arts education is the unique modal affordances that digital technology can offer when it comes to understanding form and sculpture. By providing its own sets of media-specific traits, free and simple software such as TinkerCad can highlight features and characteristics that might be taken for granted or are difficult to discover in traditional analogue sculpting. Still, as seen in both the results and previous research (Björk, 2014; Marner & Örtegren, 2013), digital technology brings with it certain understandings regarding skills, authenticity and aesthetic qualities. The digital domain is often perceived as more technological, rational and precise – which the student teachers in this study corroborated. This, in turn, can underscore a more technical discourse, yet also distinct approaches to solving a particular task, which was noticeable in the different strategies the students employed in the first workshop. One strategy can, for instance, highlight learning aspects, while another promotes aesthetic qualities in a design process. One is not necessarily better than the other; rather, they enable different aspects of learning in visual arts. Awareness of these prerequisites makes it possible to plan teaching based on specific objectives.

While a student teacher's perception of the digital domain is predominantly technological, as Klein (2021) argues, digital technologies cannot be separated from the visual culture that student teachers form part of. Their feelings and preferences are influenced by other digital references, as one student group pointed out, and sometimes their expectations do not match their own capabilities and/or the capabilities provided by the technology. This can evoke feelings of frustration and emotional disconnect, and perhaps this explains why some students found the analogue workshop to be freer and more intuitive. A challenge in visual arts education is thus bridging the subject's artisan tradition (Åsen, 2006) with values grounded in digital epistemologies in order to also bridge difficulties regarding embodied knowledge and students' relationship to materials, techniques and sensory experiences. The key here is to move between the digital and analogue domains, not in a complementary way, but with the explicit aim of transforming function and aesthetic qualities.

By challenging student teachers in this study to start in a digital domain, the digital setting could defamiliarise an everyday object for the student teachers. Perhaps this also contributed to the more explorative process in the second workshop. Digital technology should not be seen merely as a tool to refine analogue sketches or designs, nor be reduced to an "add-on" (Marner & Örtegren, 2013) in visual arts education. Instead, art educators need to explore and develop methodologies based on the opportunities the digital domain affords.

REFERENCES

Bezemer, J., & Kress, G. (2008). Writing in Multimodal Texts: A Social Semiotic Account of Designs for Learning. *Written Communication*, 25(2), 166–195. https://doi.org/10.1177/0741088307313177

Björck, C. (2014). *"Klicka där!": En studie om bildundervisning med datorer*. ["Click there!": A study of visual teaching with computers]. [PhD thesis, Stockholms universitet].

Davies, M. (2012). *Graphic design theory*. London: Thames & Hudson.

Dewey, J. (2005). *Art as experience* (Perigree trade paperback ed.). New York: Penguin books.

Erixon, P. O. (Red.) (2014). *Skolämnen i digital förändring: En medieekologisk undersökning* [School subjects in digital change: A media ecology investigation]. Lund: Studentlitteratur.

Forsler, I. (2020). *Enabling Media: Infrastructures, imaginaries and cultural techniques in Swedish and Estonian visual arts education*. [PhD Thesis, Södertörns högskola].

Hellman, A. (2017). *Visuella möjlighetsrum: Gymnasieelevers subjektsskapande i bild och medieundervisning* [Visual opportunity spaces: High school students' subject creation in image and media education]. [PhD Thesis, Göteborgs universitet].

Klein, K. (2021). Post-digital, Post-internet: Propositions for Art Education in the Context of Digital Cultures. In Tavin, K., Kolb, G., & Tervo, J. (Ed.), *Post-Digital, Post-Internet Art and Education: The future is All-Over* (p. 27-44). Springer International Publishing AG.

Knochel, A. D., & Sahara, O. (Ed.) (2023). *Global Media Arts Education: Mapping Global Perspectives of Media Arts in Education.* Cham: Springer International Publishing AG.

Kress, G. (2010). *Multimodality: A Social Semiotic Approach to Contemporary Communication.* London: Routledge.

Lind, U. (2010). *Blickens ordning: Bildspråk och estetiska lärprocesser som kulturform och kunskapsform* [The order of the gaze: Imagery and aesthetic learning processes as a form of culture and form of knowledge]. [PhD Thesis, Stockholms universitet].

Lindgren (2008). *Forskningsfältet bilddidaktik* [The research field visual arts didactics]. Göteborg: Göteborgs universitet, Institutionen för pedagogik och didaktik.

Marner, A., & Örtegren, H. (2013). Four approaches to implementing digital media in art education. *Education Inquiry, 4*(4), 1-18.

Porko-Hudd, M., & Hartvik, J. (2021). ”Coronaslöjd”. Lärarens omställning till ofrivillig distansundervisning [“Corona Sloyd”. The teacher’s transition to involuntary distance learning]. *Techne Series A: 28*(4), 1-20.

Rose, G. (2023). *Visual methodologies: an introduction to researching with visual materials* (5th edition). London: SAGE.

Schön, D. (2003). *The reflective practitioner: how professionals think in action* (Repr.). Ashgate.

Tavin, K., Kolb, G., & Tervo, J. (Ed.) (2021). *Post-Digital, Post-Internet Art and Education: The future is All-Over.* Springer International Publishing AG.

The Swedish National Agency for Education [Skolverket]. (2015). *Bild i skolan. En nationell ämnesutvärdering i årskurs 6 och 9* [The national evaluation of visual art education in compulsory school, 2015]. Rapport 423, 2015.

The Swedish Research Council [Vetenskapsrådet]. (2017). *God forskningssed* [Good research practice]. https://www.vr.se/download/18.2412c5311624176023D25b05/1555332112063/God-forskningssed_VR_2017.pdf

The Swedish Research Council [Vetenskapsrådet]. (2023). Research overview 2023. Educational sciences [*Forskningsöversikt 2023. Utbildningsvetenskap*]. Stockholm: Vetenskapsrådet.

Åsén, G. (2006). Varför Bild i skolan? En historisk tillbakablick på argument för ett marginaliserat skolämne [Why visual arts in school? A historical retrospective of arguments for a marginalized school subject]. I U. P. Lundgren (Red.), *Uttryck, intryck, avtryck – lärande, estetiska uttrycksformer och forskning* (p. 107–122). Stockholm: Vetenskapsrådet och Uppsala universitet.

Sculpting, photogrammetry and computer-aided design (CAD) in primary teacher education

Dan Tommi Hildén & Tarja Karlsson Häikiö

INTRODUCTION

The need for digital skills is growing in today's computerised world. The national digitisation strategy for the Swedish school system should be leading the way in terms of best harnessing the possibilities of digitisation to make children and pupils digitally competent and promote the development of knowledge and equivalence (Department of Education, 2017). In the Swedish National Education Agency's assessment (2020a), while access to digital tools is generally perceived as good, many pupils and teachers, especially in the lower grades, wish to use digital tools more. Overall, digitisation has had a greater impact in junior and senior high school in terms of both the access to and use of digital tools (Swedish National Agency for Education [SNAE], 2020a). Willermark (2018) writes "the school's digitisation means that the conditions for the teaching role are reshaped and that teachers need to develop new strategies for teaching, in interaction with pupils, subject content and digital technology" (2018, p. 19).

Between 2021 and 2023, a research project was conducted with primary student teachers at a Teacher Education programme at a university in Sweden. The research mainly focused on how digital tools such as VR (virtual reality), CAD programs and 3D printers relate to aesthetic learning processes and situated socio-cultural learning, and what such digital tools mediate in the development of student teachers' knowledge concerning visual arts education in primary school. The aim of the project was to reinforce primary student teachers' knowledge about new technology combined with traditional methods and the possibilities it affords in art teacher education from a higher education didactics perspective. This was accomplished by studying student teachers' visualisation of materials through sculpting and 3D design in an assignment where both analogue (traditional, manual techniques) and digital media were used as a mediators of artistic quality and individual expression. The research questions guiding the project were:

- Which difficulties arise in the shaping of an idea from physical form onto the virtual space and back to a physical form with an 3D printer?
- Which didactic implications does the assignment hold from a double didactic perspective in primary teacher education?
- How does a rotatable 3D visualisation through photogrammetry work as an assignment in the subject visual arts?

The teaching assignment studied in the research project consisted of multimodal use of analogue and digital media. Manual sculpting/shaping, photogrammetry and a CAD program (computer-aided design) called TinkerCad was used to explore how digital technology can provide new perspectives on sculpting techniques with analogue materials.

ART EDUCATION IN PRIMARY SCHOOL AND IN THE AFTER-SCHOOL CENTRE

The Swedish primary teacher programme consists of teacher studies for the after-school centre or the earlier years, grades 1–6.[2] In 2001, a reform of the teacher education system was carried out where a government bill proposed a new model for primary teacher education. Here, the training for after-school teachers was to include visual arts, music, home economics or sports (Prop 2009/10:89; Forsler, 2021, pp. 120-121). The education of primary teacher students takes a stance regarding a specialisation in visual arts as part of the Teacher Education programme to be a primary school teacher. To understand the virtual reality underlying ICT (information and communication technology), primary school pupils need to understand the visual imageries behind what they see on the screen. In the revised curriculum for compulsory school in Sweden, *The Curriculum for Compulsory School, Preschool Class and School-Age Educare*, Lgr22, source criticism and skills to use digital media are highlighted on a more specific level:

> *The pupils must be able to orient themselves and act in a complex reality with a large flow of information, increased digitisation and rapid rate of change. Study skills and methods of acquiring and using new knowledge therefore become important. It is also necessary that pupils develop their ability to critically examine information, facts and conditions and to recognise the consequences of different alternatives. /…/ All pupils must be given the opportunity to develop their ability to use digital technology. They must also be given the opportunity to develop a critical and responsible approach to digital technology, to be able to see opportunities and understand risks and be able to value information (SNAE, 2022, pp. 7, 8, authors' translation).*

In the central content for the teaching in years 1–3 and 4–6, the syllabus for visual arts states what the teaching through image production, techniques, tools and materials and image analysis should comprise:

- Photography and the transfer of images using digital tools (years 1–3).
- Photography, film and other digital image creation as well as editing of photography and moving images (years 4–6).
- Some tools and materials for drawing, painting, modelling and constructions along with photography and other digital work with images (years 1–3).
- Tools and materials for drawing, painting, printing techniques, three-dimensional work, photography, work with moving images and digital image processing (years 4–6) (The Swedish National Agency for Education, 2022, pp. 30-31, authors' translation).

Many schools have purchased 3D printers that allow objects in clay, play dough and plasteline to be transformed with photogrammetry and then printed, although many

2 Within the primary teacher programme at Swedish universities, several institutions offer one semester of studies in the subject visual arts comprising 30 higher education credits. These studies give students the authority to teach visual arts up to year 6 as well as the authority to grade the subject in their future teaching role. In primary school, the pupils are usually taught by class teachers in visual arts, while in years 7–9, or upper secondary school, visual art teachers usually have 4–5 years of training in the subject comprising 90–120 higher education credits.

schools do not use them frequently, whereas teachers also lack the skills to use such techniques. The national evaluation of visual arts revealed the need for continuing education in digital media among visual arts teachers (SNAE, 2015a, p. 39). The government, in turn, wants school time to be filled with reading books and writing by hand – not screen time (Expressen, December, 2022). The future of pupils is determined by the everyday life of school children and a clear dichotomy of opinions still remains concerning which way to go with digitisation.

Visual arts in primary school years 4–6 depends on how each school sets up its teaching. Schools can choose to put the hours in visual arts in clusters of a semester or even in a single grade in primary school, instead of pupils having visual arts every term or progressively over several years. This creates a problem whereby pupils can miss continuity in their visual development over time and where other justifications are used as reasons for planning than the pupils' right to create (Convention on the Rights of the Child, Article 31, Asplund-Carlsson et al., 2020). Hansson Stenhammar (2020) argues that the use of aesthetics and art requires a well-thought-out didactic setting to promote development and learning, stating: "Teaching and learning in the arts means developing and strengthening the pupils' motivation, critical and creative thinking, and the ability to communicate and collaborate" (2020, pp. 21, 86).

Many pupils and student teachers do not perceive the knowledge they acquire in the subjects of music, visual arts and sloyd as important after finishing primary school. Moreover, the subjects are perceived as unimportant by parents in terms of passing further studies or the students' working life plans (SNAE, 2015b). The Swedish National Agency for Education states that the ability to read, interpret, communicate with images and create images are different parts of the visual competence (2022). The visual competence, which is stressed in the curriculum for visual arts (SNAE, 2021b, p. 6), today should include lessons in which pupils can meet and try out image creation with both analogue techniques and digital tools to "stimulate pupils' creativity, curiosity and self-confidence as well as their willingness to try and put ideas into action and solve problems" (SNAE, 2021b, p. 8, authors' translation). Visual competence also includes critical thinking about images and media use, described in the curriculum as the ability to "discuss and critically review different visual messages" (SNAE, 2022, p. 29, authors' translation).

There seems to be a gap between national intentions with respect to the importance of achieving visual digital competence, including the ability to create and analyse digital and analogue images and the generally negative view of the importance of the learning outcomes provided by teaching the subject of visual arts held by pupils and their parents. The latter affects the status of the subject in teacher education and the student teachers' interest in training for it. The current study aimed to address the challenge of educating primary student teachers for future image-creating activities by investigating how a process of analogue and digital 3D modelling provides primary student teachers with both visual as well as didactic competence.

THEORETICAL FRAMEWORK

The theoretical framework of the project drew partly on a socio-semiotic perspective (Leijon & Lindstrand, 2012), partly on a haptic perspective.

Socio-semiotic perspective

Säljö (2021) argues that the use and creation of artefacts is a fundamental form of human knowledge development where thought, materiality and body cannot be separated: "artifacts arise from processes that we now call design, and they are an expression of our ability to express, develop and, in a literal sense, materialise knowledge" (2021, p. 195). The artefacts carry a history where cognition and materiality are connected to each other. Here, the character creation takes place partly based on a personal interest in relation to social staged situations (Selander & Kress, 2010, p. 33). According to Leijon and Lindstrand (2012), the sign creation which takes place in interaction with other people is a central part of the social semiotic perspective. The created sign is defined as the smallest meaning-bearing unit in a representation of any kind and can be described as a union or linking of what signifies (a form) and what is signified (meaning). Within the social semiotic perspective, it is believed that the relationship is motivated and not arbitrary (Leijon & Lindstrand, 2012). This means that there is always a connection between form and content in the signs we create and it also means that we can never completely distinguish between form and content in a representation because the form is a prerequisite for how this content can be understood (Leijon & Lindstrand, 2012).

Willermark (2018) emphasised that the development of teaching with digital technology is a complex process. When pupils build with LEGO or play three-dimensional computer games, they develop their spatial ability (Power & Sorby, 2020). Sofkova Hashemi (2019) pointed out that it is important for the teacher to ask how digital tools should be applied in teaching. Pupils do not all need to receive the same tools, albeit individualisation can be beneficial for pupils. It is not about using technology to do the same things in a different way, but about using technology to do fundamentally different things (Selwyn, 2017). Gärdenfors (2001) argued "that our thinking is spatially shaped, where the discrimination of our stimuli takes place in different ways and a bridging takes place between linguistic, sensory and motor stimuli based on a geometrically experienced, conceptual framework" (2001, p. 60).

The haptic sensation and aesthetic process

According to Karlsson Häikiö and Ericson (2017), digitisation does not exclude the need to train hand skills based on societal aspects, "but society changes as do its needs and requires a wider spectrum of methods and media for visual expression" (2017, p. 79). The hand surgeon Göran Lundborg explained in an interview with Hallonsten (2022) that when the hand is being used, this stimulates the synapses, the flow and contributes to generally increased activity throughout the brain, which affects our ability to take in all kinds of knowledge. In his book, *Handen i den digitala världen*, Lundborg notes "that the hand's creative activities in arts and crafts provide a long-awaited alternative to the digital society" (2019, p. 98). The assumption is that the interplay of hand and brain has always played a significant role in the subjects of image and craftsmanship in processing information. The distinction between eye and hand is important as the term visual usually refers to the optical, not the haptic ability to absorb information.

The visual image is ambiguous because the 3D environment is projected onto the two-dimensional (2D) retina. The haptic sensation disambiguates the visual sensation of a three-dimensional object and helps the brain create knowledge (Wijntjes et al., 2009). Mills (2016) believes there has been increased interest in the material dimensions of learning, where the term "material" refers to anything that has mass or matter and occupies physical space. With this in mind, and related to the optical sensation, Mills seeks to establish socio-spatial, socio-material and sensory literacy as a concept to expand the more established paradigms of the concept of literacy.

Marner (2005) writes "The knowledge we get through the senses does not exist alongside cognitive processes but is itself a cognitive process" (2005, p. 131). Marner believes that different media create meaning and that the bodily senses are important in learning. The body is a medium for the purpose of creating meaning. Aesthetic learning processes emphasise that the learner is a co-creator rather than merely a receptacle of raw information (Lind, 2010). The teacher is a stager of learning situations and a supervisor rather than a mediator of already known knowledge. Knowledge is found in and through various media rather than only within the written language (Liberg, 2008). Learning grows out of dialogues between children and adults rather than from the teacher's monologue (Hansson Stenhammar, 2020; Marner, 2005).

Lindström (2009) describes the creation of meaning within aesthetic subjects as four forms of learning *about, in, with* and *through* art and media (2009, p. 57). These forms of learning can be used for the purpose of analysing the work processes of visual arts and sloyd. Lindström's forms for learning related to art and media have also been highlighted by several researchers (e.g., Hansson Stenhammar, 2020; Mäkelä, 2011) where learning about can mean that pupils learn how tools are implemented. Learning in refers to the pupils' use of previous knowledge while developing new knowledge. Learning with is not subject-specific, but pupils can, for instance, work across subjects in other situations. Finally, pupils can learn through something, which is not subject-specific, it can for example be that pupils are creative problem solvers.

METHODOLOGY

For the empirical part of the project, the sculptor and art teacher educator (Hildén) designed didactic interventions comprising learning processes of analogue and digital sculpting with primary student teachers. Here, meaning-making and the communicative, social actions through three-dimensional making with manual techniques as well as digital tools were the fundamentals of the learning design drawing on a multimodal perspective (Leijon & Lindstrand, 2012). The multimodal perspective meant that several different modalities were simultaneously active in the learning process (Kress, 2010; Selander & Svärdemo-Åberg, 2009). The didactic interventions were documented by Hildén´s autoethnographic notations, the students' visual logs and visual ethnographies (Pink, 2021; Rose, 2016). Karlsson Häikiö processed the textual and visual information from the student teachers and Hildén and observed the teaching sessions. This altogether constituted the methodology for producing the empirical material.

Documentation of the learning process – autoethnographic writing and a visual log

Hildén's autoethnographic work concerned how to combine traditional sculpting techniques with new design techniques such as rotatable 3D visualisation through photogrammetry and CAD-based design. The material in the study was based on observed discussions with primary student teachers in visual arts lessons and their process logs with permission to use the material in research and presentations. The primary student teachers' log writing was intended to increase understanding of the more invisible dimensions of learning (Biesta, 2006, 2014) in teaching situations. Here, it was important to ask where learning takes place, how it is done, and what the students are expected to learn. A question raised by Tombro (2016) with respect to students concerned the difference between personal writing and academic writing (2016, p. 30), an aspect that is often problematic in studies. Tombro stressed the importance of the material created being personal and not intended solely for the supervising teacher to assess. This approach can help students to distinguish the so often hard-to-reach private from the more general parts in their studies. Students need to see the connection between their material, their doing and the result, and that all of these aspects form part of the learning process. This is a particularly relevant issue in art teacher education and must be clarified since visual arts is characterised by both image production and reflection through verbal and written response, a dichotomy that many visual art teachers find ambiguous (Karlsson Häikiö, 2021).

The use of the primary student teachers' process logs contributed to the ethnographic method in the project. Hildén himself, having collected material in his educational practice as an art teacher educator, was inspired by Tombro's ideas (2016, p. 33) about writing notes, in this case via a text and a visual log, during the creation process and creating methods for collecting autoethnographic material during an artistic process. Tombro argued that it is important that all of our sensory impressions have a place in an autoethnographic material (2016, p. 32). Adams et al. (2015) stated that autoethnography is a qualitative method that offers nuanced, complex and specific knowledge about particular lives, experiences and relationships rather than general information about large groups of people.

The textual and visual research material comprises both Hildén's autoethnographic material and observed material from the lessons, as collected by Karlsson Häikiö. Hildén also conducted an interview with a technician at the teaching university (26 October 2021). The lessons with the primary student teachers were conducted through group learning and an instructive learning situation defined as blended learning, combining classroom instruction with computer-aided instruction, or online-based learning (Graham, 2006). The material collection was from an assignment that was made with several groups of primary student teachers attending a lesson with photogrammetry and TinkerCad between 2021 and 2023.[3] The study of the project consisted of four groups with about 20 primary student teachers who were trying out TinkerCad for the first time, except for a few who already had experience with the program.

Research ethics

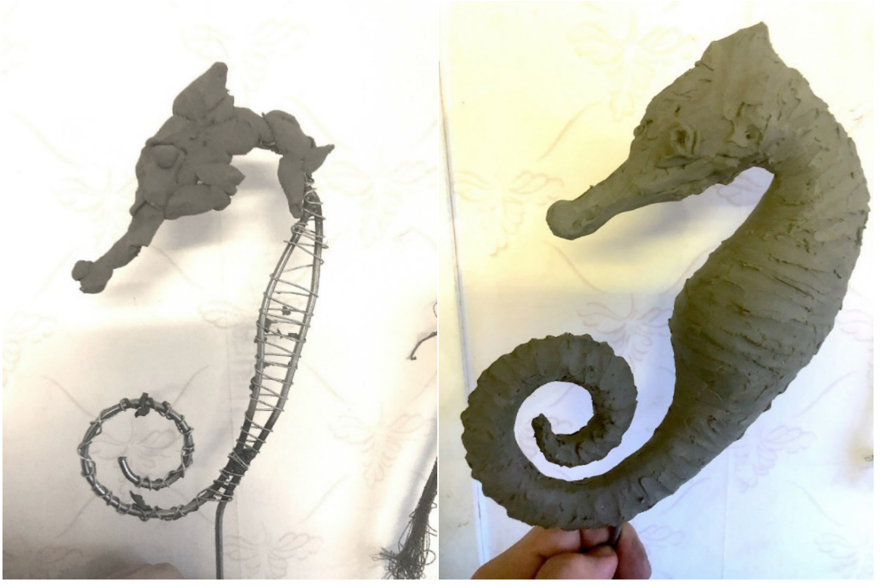
The project was conducted based on the ethical requirements of good research practice (The Scientific Council, 2017). The student teachers were informed of the four criteria on information, consent, accessibility and confidentiality that is required in all research, and gave consent to partaking in the research project after being informed verbally by signing a consent form on the use of both text and visual material. The material was managed, transcribed and stored according to the rules for data storage of the university.

EMPIRICAL – PART: ART EDUCATION OF PRIMARY SCHOOL STUDENT TEACHERS – 3D SCULPTING PROJECT

Analysis

The empirical data showed that not all primary student teachers remember the visual arts classes from compulsory school and seldom possess experience with explorative work processes. The lack of connection with previous experiences made them feel insecure in the divergent landscape of the subject and in need of scaffolding in the development of their abilities to understand the teacher's guiding role. In the study, the primary modelling became crucial to understand form as well as the relationship between two- and three-dimensionality. Further, including didactic elements in the process to understand the connection between creating and learning were important considerations together with the reflections on the critical aspects that must be taken

3 Lessons observed on 15 September 2021, 18 October 2022, 15 March 2023 and 15 April 2023.



Images 1 and 2. Sculpture of a sea horse in metal wire and clay (https://skfb.ly/oonSD). Photo: Dan Tommi Hildén.

into account in order to stage learning in school (Lindström & Pennlert, 2016).

The research project was based on Hildén's teaching in a university course for primary student teachers comprising 30 higher education credit points. The starting points of the assignment to the primary student teachers was for them to be able to see the connection between the use of analogue (traditional, manual techniques) and digital techniques in the visual arts classroom with primary school children. Another starting point was to create an understanding of the use of digital tools and CAD-based media. In this respect, the skills of handling malleable media, like clay, provide a way of creating an understanding of the relationship between two- and three-dimensional forms. Hildén built his didactical intervention on the concept of *double didactics* (Hildén et al., 2024), where the future teaching of pupils in primary school was the intended goal of the primary student teacher's learning.

Background to the 3D project – trying out the model of 3D sculpting

Hildén was interested in exploring how manual abilities can be taught through online-based education and how the optical and haptic qualities of sculpting can be effectuated in the teaching with primary student teachers. The question was whether it is possible to transfer a manual doing into a digital form and back again? A major obstacle with the use of online-based technology like TinkerCad is that the teaching is then based on optical and audio communication. The haptic and the tactile areas are neglected as is the spatial one, even when the teaching takes place in the same classroom through individual computers. In sculpting before the 3D visualisation, it is important to experience the sculpting haptically with the fingers and touch to be conveyed virtually and optically with the eyes. To test his interest and prepare for the didactical intervention, Hildén tried using photogrammetry as a method to digitise a sculpture, a seahorse called HippoCampus

(Images 1 and 2). He selected suitable illustrations of seahorses from old scientific books as a starting point and inspiration. He welded together the steel frame that holds the clay in place and the sculpture upright during the work while at the same time trying to convey life and movement by working the surface. The model, transferred through photogrammetry and made virtual, can be twisted and turned on the screen to see the size, surface and the traces the hands have left behind. In this way, it can be seen in and experienced as a 3D model and manipulated further if required. Hildén experienced this as a method coming as close as the optical sensation can get to the haptic sensation.

Photogrammetry

Photogrammetry is the art and science of extracting 3D information from photographs. It is a field of technology where photographs are used, among others, for various kinds of measurements such as for determining the exact positions of geographic elements like topographic maps, but also to create rotatable 3D models of photographed objects or 3D visualisations of various kinds. Historically, the earliest photogrammetry may be traced back to the 15th century when analysing the use of geometries in paintings. The concept and principle are over 100 years old. Projective geometry in the mid-17th century was the next step in development, entailing analysis of the relationship between an object and its projection onto a surface. Aimé Laussedat is considered to be the creator of photogrammetry. He applied the technique for the first time in 1849 at Hôtel des Invalides in Paris. Dr Albrecht Meydenbauer (1834–1921) was the first to use the word photogrammetry in 1893 (*History of photogrammetry*, u.å.).

Today, it is digital technology that has given the principle a considerable boost. Along with private drones and high-resolution cameras, photogrammetry has led many to digitise 3D models of their surroundings. A photogrammetry model takes shape through triangulation. Triangulation in this sense means taking overlapping photographs of an object, structure or space, and converting them into 2D or 3D digital models. It is the different positions of the camera relative to the photographed object that determine what shape the 3D object should take. 3D models created through photogrammetry retrieve texture information directly from the photographs. The result can therefore be very realistic and similar to the original (SND; *Photogrammetry*, 2019-10-29, pp. 5–6).

The assignment for the primary student teachers

The assignment for the primary student teachers arising from Hildén was to think about how they could use 3D and TinkerCad with pupils in primary school. His interest in developing the assignment with the CAD program stemmed from a desire to figure out a didactic progression in his teaching in the subject visual arts, both for student teachers and especially for pupils in school. Hildén's thinking was to clarify for the primary student teachers how pupils can work in clay and after this use photogrammetry based on photographing the object, and then finally print the objects designed in the CAD program using a 3D printer at primary school. The level of use of photogrammetry and CAD programs should, of course, be adjusted to the school year and level of the pupils.

The CAD program used in the assignment was TinkerCad, a free-of-charge web application for 3D design (www.tinkercad.com). It can be used on different levels of knowledge and skills in computing, making it usable with small children as well as in work where advanced manipulations are needed, like object-design, environmental design, architecture and so on (see Buhl and Skov in this issue). The assignment was made up of several parts:

Choosing an everyday object, sketching, sculpting and photographing

1. choosing an everyday object,

2. sketching drawings of the everyday object with pencil, chalk or charcoal,

3. sculpting the everyday object in clay or another moulding material,

Modelling a 3D object in the CAD program, documenting and having a didactic conversation

4. working with the CAD program (TinkerCad) and making a virtual 3D model of the everyday object,

5. documenting the working process by photographing the sketches and the clay sculpture and putting them into a visual log, and writing comments about the process,

6. presenting the work to the other student teachers and having a didactic conversation about the learning process supported by the art teacher educator,

Photogrammetry and 3D printing a virtual replica of the everyday object

7. photographing the sculpted version of the everyday object to prepare for the photogrammetry where about 70–100 photographs must be taken of the clay sculpture to prepare for the photogrammetry,

8. photogrammetising the everyday object by sending the photographs to a digital program to transform them into a virtual model for 3D printing,

9. carving out a virtual replica of the sculpted object digitally,

10. printing the TinkerCad version of the everyday object using a 3D printer (optional).

RESULT – DESCRIPTION OF PROGRESS WITH THE PROJECTS

Prior to the lesson, the primary student teachers were instructed by the art teacher educator to draw images in different techniques and shape physical objects in clay beforehand, to train their perceptive (optical), haptic and kinetic skills. Before the activity commenced, Hildén explained that a physical object must be experienced haptically with the touch of the fingers besides being conveyed optically with the eyes before going virtual. This made it important to draw the object and make the sculpture in clay and use only the hands without any tools. The making by hand needed to come before the 3D visualisation. In the introduction to the lesson, the art teacher educator talked about the connection between brain and hand and linked this to the course literature, describing the relationship between the optical and the haptic.

As further preparation, the primary student teachers were instructed to create a process log using both text and visual representations where their learning process was to be documented as a basis for the subsequent didactic conversation with the other student teachers and Hildén. The student teachers were instructed to save their drawings and photographs of their process and objects in the process log and to continuously reflect on their work by documenting and writing in Canvas, the web-based learning management system used by the university in question.

Choosing an everyday object, sketching, sculpting and photographing

The lesson started by asking the primary student teachers to first: 1) choose an everyday object, for example a cup, to work with;

Image 1. Drawing in charcoal of a coffee mug by a primary student teacher. Image 2. Drawing of a cup and a cup modelled in plasteline made by another primary student teacher. Photo: Tarja Karlsson Häikiö.

2) sketch the chosen everyday object with pencil, chalk or charcoal; and 3) sculpt the object in clay or some other mouldable material. The primary student teachers started drawing sketches with pens, charcoal etc. The student teachers were requested to make the drawings of their clay-cup at different angles. They worked with shading in the sketching of dark–light. In this shading, they needed to deal with the relationship between the physical reality and spatiality. Several primary student teachers decided to draw a cup or a mug as their everyday object (Image 1). You can almost smell the coffee from the slightly blurred, foggy expression of the drawing.

Understanding the spatiality–form relationship is also part of the work with different mouldable techniques, rolling, thumbing etc. The next step for the student teachers was to transform their sketches of the everyday object from a two-dimensional drawing into a three-dimensional sculpture in a moulding material they had selected, which could be clay, plasteline or some other material (Image 2). The student teachers started shaping their chosen everyday object in a mouldable material and later showed their sketches and sculpted objects to each other. What the primary student teachers had chosen to create did not always turn out as they had imagined. The artistic process thus included dealing with failure and being able to see that things which are done do not always turn out was expected, but can turn out to be something else, which provides the conditions for moving forward in the process.

Observations notes show that one of the student teachers shows the sketches he made of his mug from his process log. The art teacher educator comments that the student teacher has come a long way with his idea based on the sketch. Sketching is like thinking out loud, but visually instead, he says. The student teacher has made a prototype for a tea light holder (Image 3). The art teacher educator talks about the problem of drawing the mug from the clearest side and the difficulty with the drawing to show that it is a mug, and to create an illusion of three dimensions where one must also understand what is not visible, or what is at the rear. He talks about tenderness in

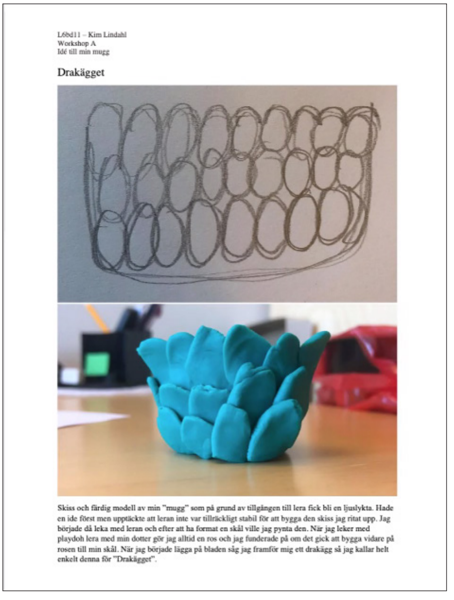


Image 3. Photo from the process log of a primary student teacher showing the drawing and the plasteline model of a tea light holder. Photo: Dan Tommi Hildén.

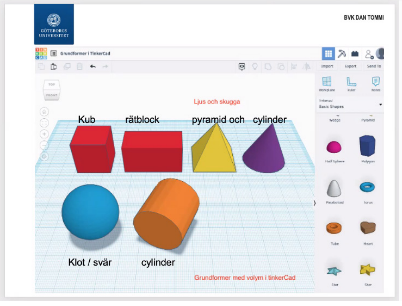
the images, a quality in the images created through the expression of the material. The teacher educator talks about perfection and the the student teachers' experience of their own creations and brings a didactic dimension into his argument and talks about the teaching work in the upcoming role as a teacher. The difficulties in drawing three-dimensional objects are the same for pupils in school. He talks about how the assignment is a way for the student teachers to gather ideas for their upcoming teaching role and to obtain ideas about what can be done with the pupils.

Modelling a 3D object in the CAD program, documenting and having a didactic conversation

The next step for the primary student teachers was to learn to use the CAD program and to digitise their everyday object into a 3D model. When the student teachers were content with their creations, they were asked to set up an account in the TinkerCad program. TinkerCad is made for teachers and there are various commands to choose from and the art teacher educator showed how this could be done. TinkerCad requires no download and can also be used with a tablet computer. This is an advantage if the work must be done in a classroom. The fact that TinkerCad programs are free-of-charge also makes them suitable for school budgets.

The art teacher educator initially goes through the functions of the TinkerCad program since the student teachers must first learn to work with basic shapes (Image 4). The student teachers are then given time to learn how to work with basic shapes like cubes and cylinders in TinkerCad. They had different experiences with solid modelling, which is based principally on standard geometric shapes, and can be combined in various ways, as mainly developed from the Boolean operations of subtraction, addition and intersection. The student teachers needed to understand how the 3D shapes are presented through shadows in a 3D environment on the screen. The 3D sculpting process requires 2D and 3D thinking where the physical object's transformation into three dimensions is part of an image-making process. The advantage of virtual objects is that they can be presented in varying sizes to find the optimal size for the final work. What proves difficult is forming the idea of size in the virtual space, or the relation between the image space and representation of spatiality in the image. How big is the object supposed to be? Another advantage of virtual objects is that they can be presented in varying sizes and scales to determine the optimal size for the final work.

During the activity, the primary student teachers frequently ask questions. How does the board, or worktable in TinkerCad, rotate? The art teacher educator is happy to show and encourages the student teachers to ask each other. He instructs and shows how to see the worktable in the CAD program from all sides. The student teachers start asking each other questions in the chat.



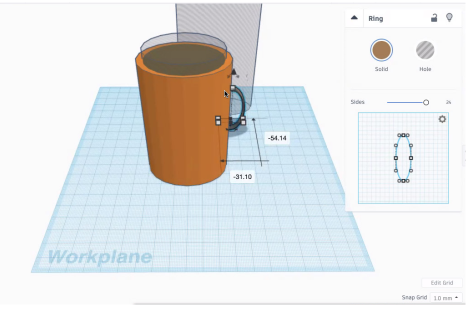


Image 4. The TinkerCad board of options of forms to use while building a virtual artefact. Image 5. The TinkerCad board of one of the primary student teachers showing how to use the function Hollow to make the hollow centre in the virtual artefact of a coffee mug. Photo: Tarja Karlsson Häikiö.

How do you chop off the top of a cone? The art teacher educator shows. After a while, when the student teachers are more familiar with the CAD program, the art teacher educator gives them an assignment to create their clay-cup in TinkerCad based on their sketches and to then design the cup on the board with the shapes in the CAD program (Image 5). In this phase, problems often appear since the student teachers create a more generic kind of cup compared to their drawings, depending on their lack of knowledge with handling the CAD program and its design tools.

The drawings, the object in clay along with the 3D modelling with TinkerCad formed the basis of a didactic conversation between the art teacher educator and the primary student teachers during the lesson. A student teacher asks about how to make a cup shape. The art teacher educator begins by showing how to create a form and then works on it in front of the students. Another student teacher suddenly instructs the art teacher educator and suggests that he use a different form that could work better. The art teacher educator tries this out and it works well. He says that in the modelling process you do not need to know everything, but it is important to learn enough to be able to use the program at a basic level. The student teachers then advise each other to watch YouTube clips that they believe provide considerable clarity. The student teachers give each other more tips on how to do things and show each other functions in the CAD program and state that it is good to look at the object from several angles and to constantly twist and turn the everyday object on the screen.

In the next phase, the primary student teachers show their drawings and their formed objects and describe their thoughts about the process to each other. One student teacher, who has a 3D printer at home in the basement, has already completed the process in TinkerCad. Her idea was to create a square mug so that it would fit in the dishwasher better. One of the primary student teachers shows her mug and says that it was tricky to put the hole in it. She says that she worked on alternating between the functions Solid and Hollow in the CAD program and solved the task that way. The art teacher educator tells the student teachers that it is possible to work with the transparency function in the program, which enables, for instance, a hole to be made in the mug and the form to be altered. Another student teacher wishes to show how he made his mug. The student teacher was inspired by a drinking mug and a coffee bean. He says that it can be good to have two handles in case you are frozen outside and then it is good for the cup to have mittens (Image 6).

Another student teacher worked on a

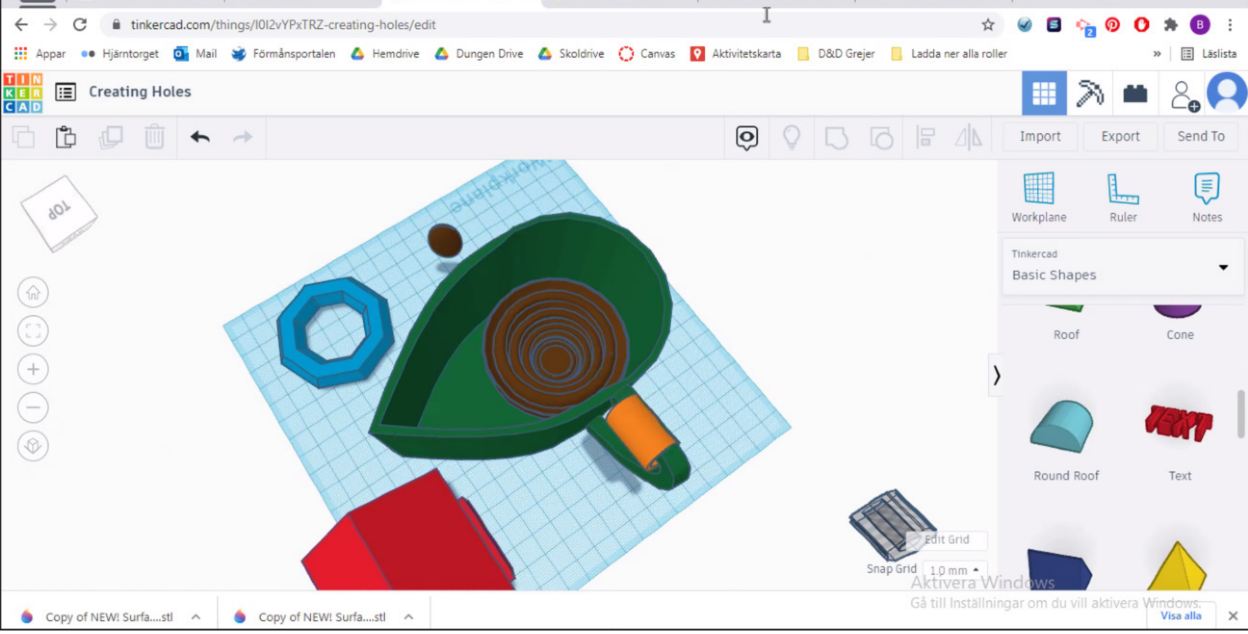


Image 6. A model of a mug that is shaped to pour out liquid, seen from above. Photo: Tarja Karlsson Häikiö.

car that is a more advanced and complex form to shape. The student teacher had not double-checked the measurements. He discusses: What level of difficulty should be assigned to primary school pupils? Maybe they do not think a mug is so much fun, for example? Maybe it is more fun to solve a problem or choose another object that the pupils like for different reasons?

One student teacher says that she fumbled a lot in her work process, but when she watched how the others were doing it, she started trying, and then it became more fun. She shows several different mugs to the others. She says that it is about cracking the code for how to work with the program between the physical and the virtual, albeit the process is time-consuming and that she made the same mistake several times before the process functioned. The art teacher educator comments that this is a perfect example from a teaching point of view, where it is important to understand that this is exactly how it is in the classroom with pupils; namely, they make the same mistakes over and over again before they learn. You must be patient.

Another student teacher shows her sippy cup. She has worked on scaling different forms and had tried to understand how different forms can be used in relation to each other. The student teacher notes that it helped a lot to hear the other student teachers' problems and ideas because it broadened her own frame of reference regarding what can be done in the CAD program. It has been fun, says the student teacher, but there is still a long way to go in terms of knowledge to make things that you would like to use professionally or privately. The art teacher educator asks if she would consider working with this at school? The student teacher believes that while it may suit some pupils, other pupils may like to work with analogue materials instead.

When the student teachers have succeeded in creating a cup in TinkerCad, the art teacher educator and the student teachers discuss different strategies for the making-process. Which differences did they notice? And how could they use the differences in their becoming teaching? Most of the primary student teachers are frustrated when it comes to the use of digital tools, while manual techniques are experienced as easy. They reflect and think that this will also apply to the pupils in primary school. The student teachers understand the didactic 'thinking'

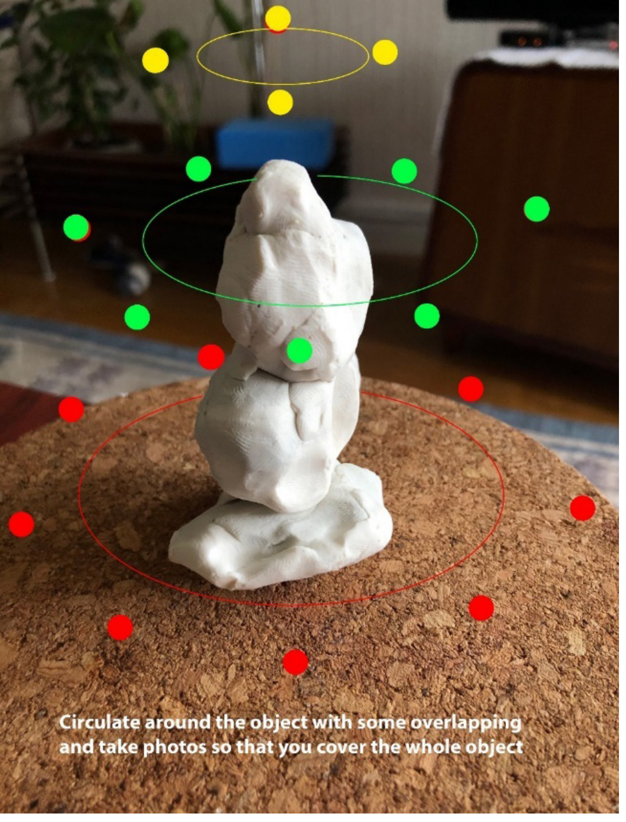


Image 7. A thought model of the positions to use in photographing an object as part of photogrammetry from all sides with up to 100 photographs. Image 8. A 3D printed object in front of a TinkerCad-modelled rabbit made by one of the primary student teachers after becoming more familiar with the program and making more advanced items. Photo: Dan Tommi Hildén.

they have to do to be able to make the cup with their hands to subsequently be able to make the work easier in both the digital and virtual worlds. The visual storytelling and expression in immersive experiences can be anything from figurative and realistic to purely abstract and be based on film, photogrammetry, computer graphics etc. (The Swedish National Heritage Board, April, 2021).

Photogrammetry and 3D printing a virtual replica of the everyday object

The next step in the process was to use photogrammetry. With photogrammetry, a model takes its shape through triangulation where an object is photographed from all sides to obtain as much information as possible about the object. In this case, the art teacher educator instructed the student teachers to photograph their sculpted everyday object from all angles using 70–100 photographs (Image 7). After the photographing, the information was sent to a digital program to permit further work on the object virtually – the object is photogrammetised. When the object is transferred by photogrammetry, there is a virtual replica of the object that should be 'carved' out virtually using the tools available in the program. Here, the student teachers needed to find the object in the virtual space in the computer program and then 'carve' out the object using a tool that erased the virtual material around the object. This proved to be a very time-consuming activity that required a lot of patience. After this, the object could be transferred to the TinkerCad program and placed on the virtual board for further manipulation.

The student teachers discuss primary school didactics during the lesson. They agree that photogrammetry is probably the most interesting as a technique for early years pupils, where play forms an important part of the studies. The primary student teachers suggest that pupils could design their own playing objects that later on could be printed out and used as small toys or as game pieces in board games that also could be designed by the pupils (Image 8). The student teachers sees here the possibility for making progress where the photogrammetry could be favourably used with younger pupils in early ages, while the CAD design could be used in the later years of primary school or on the upper secondary level. They also discuss if maybe the photogrammetry should be done by the teacher in the first case, while in the second case the pupils could perhaps learn to use a 3D printer themselves. Here, they suggest collaboration, for instance, with the teacher in technique or sloyd subjects.

The art teacher educator constantly talks with the student teachers from a primary school teaching perspective. Pupils think that 3D is something that only exists in a computer or phone. He refers to children's gaming and that many pupils are used to seeing 3D representations. He asks the student teachers if they think the pupils really understand what they see? The art teacher educator talks about progression in knowledge of shape and colour from grades 1–3 to 4–6. In grades 1–3, he believe s that pupils need to work concretely with materials while pupils in grades 4–6 could move on to the digital.

The progression in the teaching between ages is one aspect discussed during the TinkerCad lesson. In the interview Hildén has made with Joacim Harrysson, a 3D technician at the university, Harrysson stress the importance of working with loops and being an ambassador for 3D work. By loops, he means that children and students should be introduced to 3D and CAD in a progression based on their age and with an emphasis on the fun, where the technical aspects should be given more and more space the older the pupil or student becomes. In the teaching with younger children, who do not yet have the right concepts language-wise, the tactile and bodily-sensory experiences are a basis for being able to understand the world around them and later on for them to be able to find the right words (Karlsson Häikiö, 2018). These experiences then form the basis for developing an understanding of other things and phenomena on an abstract level.

In the last step, the primary student teachers were able to print out their CAD designed objects using a 3D printer. While this was free to choose, it also entailed a small cost for the student teachers. The person responsible for the 3D lab (Joacim Harrysson) show them the 3D printing process and the different options for printing available at the university. He also tell the primary student teachers what is important to take notice of while printing and what to think about in case the student teachers want to have a 3D printer at their schools in the future. He also offer especially interested student teachers the opportunity to contact him for more advice and instruction.

DIDACTIC IMPLICATIONS FOR HIGHER ART DIDACTICS – A DISCUSSION OF THE RESULTS

Hildén's teaching took its stance from the double didactic perspective (Hildén et al., 2024). The role of technology in the school subject visual arts from such a perspective means that technology is functioning as a tool in art education with primary student teachers, but will subsequently be effectuated with pupils in school. Hildén's aim was to teach student teachers to see the potential held by the combination of analogue and digital media. He wanted them to try out handling the process from two-dimensional drawing and sculpting and to transform this into a virtual object with a CAD program. To strengthen the learning process, he used textual and visual process log-writing. The primary student teachers' logs consisting of text and images provide a tool to help the art teacher educator gain insight into their thoughts, considerations and choices, but also as a means for assessment. Methodically observing oneself and one's actions constitutes an important educational tool. By using a process log, both parties – the art teacher educator and the student teacher – have access to the student teachers' written materials, which the supervisor also needs to read to be able to follow each student's learning process. Through use of self-observational data, thoughts and feelings as they occur in their natural context can be made conscious (Chang, 2016, pp. 78–79).

Seen from a socio-cultural perspective, this means that the way we think, communicate and learn is strongly dependent and influenced by the context and environment in which it takes place (Karlsson Häikiö & Ericson, 2017). The traditional way of working analogically and spatially is seen by many as the norm. There are fears of fragmentation and missing out information or content in the teaching, especially when the physical space does not bring the parties together in the same room in a net-based conversation and thoughts and ideas are not shared in that room. Based on our study, the learning of the student teachers can be problematised. Would more efficient learning have taken place had the art teacher educator instructed the student teachers and who then followed the instructions, instead of having a more explorative approach whereby the student teachers were part of the process via their own and mutual trial-and-errors? How does this kind of approach affect the power structure between the art teacher educator and every individual student teacher when the art teacher educator is still the one to assess the assignment and the university course?

Today, it is possible to let computers and machines do part of the work, even in school. When computers do part of the work such as with 3D printing, it is still the individual who creates and designs (Borg et al., 2021). For the teacher in a teaching situation with computers, it is important to ask where the learning takes place, how it is done, what the pupils/students are expected to learn. There is a need to redefine learning when digital tools enter teaching in school and where traditional techniques are combined with new technology. The relationship between the virtual and the bodily senses, the optical and the haptic, becomes even more important to address because the thinking is expressed through our hands manually. Mills' (2016) ambition to create a *sensory literacy* aligns with the socio-material aspirations of today. In this context, and through the expanded digital opportunity, the pupil or student has to form knowledge where the computer also includes a spatial dimension, or the virtual space and the mental space of the pupil/student (Gärdenfors, 2001). For the teacher in this hybrid situation, it is vital to ask where the learning takes place, how it is done, and what the pupils/students are expected to learn. Perhaps it is more about simply redefining learning when digital tools enter teaching. In such a context, and through the expanded digital opportunity, the pupil/student has to form knowledge where the computer also includes a spatial dimension that requires in-depth thinking. This contributes to the world of the pupil/student being stretched in all dimensions at once, where knowledge is mediated in a way that takes advantage of all these dimensions and happens as a stretched knowledge dimension (Fleischer & Kvarnsell, 2015, p. 86). The breadth of possibilities in the content of visual arts creates a wealth of references to choose from, among which there are options to take different theoretical and other perspectives and positions linked to issues of, for example, gender, knowledge, power etc. (Lind, 2010), through a wide range of visual and rhetorical techniques (Skåreus, 2014, pp. 14, 117).

The use of technology in visual arts education raises some concerns with regard to learning and new thinking patterns. A combination of analogue and digital techniques as well as the development of a critical ability to analyse and interpret images (material and sources of images) are highlighted more clearly in Lgr22 (SNAE, 2022). Now that digital images have become central sources of information in global society, the lack of accessibility to new media is seen as a major problem in schools along with teachers' lack of digital competence (SNAE, 2015a, p. 22). What does this virtual reality look like and how can the stretched dimension become part of the visual arts classroom? There are possibilities for two-way communication in speech, writing, image, moving image in real time and, ultimately, the virtual reality can include touch and other activity where the participants in the act of communication can influence the simulated event in real time (Marner, 2005). When writing about virtual reality, the Swedish National Agency for Education (2018) states that it is difficult to say anything general about the effects of using digital technology in school. The research evidence shows that the existence of digital media has not clearly established positive or negative effects on pupils' learning. What we do know is that pupils who are experienced with digital games have an easier time embracing learning in virtual worlds (Han, 2017). The technical equipment that most pupils, teachers and schools have today is sufficient to digitise a physical object and – for instance – TinkerCad is free of charge. The computer, this mediating tool used for knowledge formation, allows lingering in a kind of space accompanied by very specific conditions for social interaction.

CONCLUSION

The aim of the described project was to contribute to the enhancement of knowledge of sculpting, photogrammetry and CAD (computer-aided design), particularly the use of TinkerCad, in visual arts education with primary student teachers. Teaching in higher art education is a sensitive situation where trust and sensitivity must be established between student teacher and art teacher educator as a starting point for the teaching conversation. A good and comprehensive basis allows both parties to be sufficiently open in the conversation and for the student teachers to be able to see various opportunities to be able move forward with their artistic work and didactic reflections. As a supervising art teacher educator, one needs to acquire specific knowledge about a student teacher's work process, which is why they are often asked to keep a logbook or other equivalent documentation on their process. Drawings and sketches are embryos or first notes about ideas or thoughts that may in the future become works of art or ideas for teaching. The method combining classroom instruction with computer-aided instruction, or online-based learning, with writing a reflective log was used as a way to systematically reflect on the primary student teachers' own processes. Information and connections are often gathered, which are interesting to discover later in the process. The method of writing a log about the learning process was used as a way to help the primary student teachers to see important and relevant moments and use this material as a basis for didactic conversations.

The research project showed that a combination of new technology (photogrammetry) and computer-aided design (TinkerCad) together with writing a textual and visual process log can create a sufficient basis for a constructive didactic conversation from a double didactic perspective in primary teacher education. The art teacher educator wanted to influence the future primary student teachers not to skip important, more traditional, steps to access modern technology and the possibilities that it offers. Another question was, from a double didactic perspective, how to create an understanding about pupils concerning the new social and spatial dimensions that virtual reality offers in primary school. The conceptual space, defined by Gärdenfors, is a way of describing parts of the learning process that takes place in the transformation between two-dimensional images and a three-dimensional form. The transposition of the visual and spatial knowledge between the two-dimensional images and the three-dimensional has to do with both optical and haptic dimensions where senses and thought interact.

REFERENCES

Adams, T. E., Holman Jones, S., & Ellis, C. (2015). *Autoethnography.* Oxford University Press.

Asplund-Carlsson, M., Karlsson Häikiö, T., & Sundhall, J. (Red.) (2020). *En lag för barn; Kulturvetenskapliga perspektiv på barnrättskonventionen* [A Law for Children; Cultural studies perspectives on the Convention on the Rights of the Child]. Lund: Studentlitteratur.

Biesta, G. (2006). *Bortom lärandet: demokratisk utbildning för en mänsklig framtid* [Beyond learning: democratic education for a human future]. Lund: Studentlitteratur.

Biesta, G. (2014). *The Beautiful Risk of Education*. Boulder: Paradigm Publishers.

Borg, R., Porko-Hudd, M., & Hartvik, J. (2021). Introducing Maker-Inspired Technology in the Finnish Craft Subject – A Case Study from One School. *TechneA - Forskning i slöjdpedagogik och slöjdvetenskap, 28*(2), 313-321. https://doi.org/10.7577/TechneA.4418

Department of Education [Utbildningsdepartementet] (2017b). *Ökad samverkan kring praktiknära forskning för stärkt vetenskaplig grund i skolväsendet Dir. 207:27* [Increased collaboration around practical research for a strengthened scientific basis in the school system]. Accessed 23rd of July 2023: https://www.regeringen.se/rattsligadokument/kommittedirektiv/2017/03/dir.-201727/

Fleischer, H., & Kvarnsell, H. (2015). *Digitalisering som lyfter skolan - teori möter praktik* [Digitization that lifts the school - theory meets practice]. Gothia fortbildning.

Chang, H. (2016). *Autoethnography as Method*. Routledge.

Forsler, I. (2020). *Enabling Media: Infrastructures, imaginaries and cultural techniques in Swedish and Estonian visual arts education* [PhD Thesis, Södertörn högskola].

Graham, C. R. (2006). Definition, Current Trends, and Future Directions. In C. J. Bonk (Ed.), *Handbook of blended learning: Global perspectives, local designs* (s. 3-21). San Fransisco, CA: Pfeiffer Publishing.

Gärdenfors, P. (2001). *Conceptual Spaces; The Geometry of Thought*. MIT Press. Mass.

Hallonsten, A-K. (2022). Hjärnforskare: Därför är skapandet nödvändigt [Brain scientist: Therefore creation is necessary]. *Yrkesläraren*, (01-2022).

Han, H-C. (2017). iSee: Teaching Visual Learning in an Organic Virtual Learning Environment. In E. Anttila, T. Barret, P. Webster, & B. Haseman (Eds.), *International Journal of Education & the Arts, 18*(38). http://www.ijea.org/v18n38/

Hansson Stenhammar, M-L. (2020). *Fritidshemmets pedagogiska uppdrag - undersökande, estetisk och ämnesövergripande arbetssätt* [The leisure center's educational mission - investigative, aesthetic and interdisciplinary working methods]. Stockholm: Natur & Kultur.

Hildén, D., Karlsson Häikiö, T., & Nordström Graf, R. (2024). Förtrogen med bild - Visuellt kunniga lärare [Familiar with images - Visually literate teachers]. In Forsler, I., Magnusson, L. O., & Öhman, E. L. (Red.), *Bild och visuell kultur. Undersökande bildundervisning i grundskola och fritidshem.* [Visual arts and visual culture. Investigative teaching in visual arts in primary school and after-school care]. Lund: Studentlitteratur.

History of photogrammetry. Center for Photogrammetric Training. Accessed 19th May 2021: https://www.ubc.ca/search/refine/?q=history+of+photogrammetry&label=Department+of+Geography&site=*.geog.ubc.ca#gsc.tab=0&gsc.q=history%20of%20photogrammetry&gsc.page=1

Illeris, H., Buhl, M., & Flensborg, I. (2004). Visual Culture in Education. *Nordisk Pedagogik*, 4(24), særnummer.

Karlsson Häikiö, T., & Ericson, K. (2017). Kunskapsbildning genom visuella och geografiska markörer i bild- och geografiundervisning [Knowledge formation through visual and geographical markers in visual arts and geography teaching]. In Häggström, M., & Örtegren, H. (Red). *Visuell kunskap för multimodalt lärande*. Studentlitteratur: Lund.

Karlsson Häikiö, T. (2018). Aesthetic activities and art-based projects as cultural tools. T. Jokela, & G. Coutts (Eds.), *Relate North: Sustainable Arts and Design in the Arctic and the North* (p. 52-78). Rovaniemi: Lapland University Press.

Karlsson Häikiö, T. (2021). Potentials and problem areas in assessment in visual arts education in Sweden. *Educare - Vetenskapliga Skrifter*, (2), 68-112.

Kress, G. (2010). *Multimodality. A social semiotic approach to contemporary communication*. Routledge.

Leijon, M., & Lindstrand, F. (2012). *Socialsemiotik och design för lärande - Två multimodala teorier om lärande, representation och teckenskapande* [Social semiotics and design for learning - Two multimodal theories of learning, representation and sign making], *17*(3–4), 171–192.

Liberg, C. (2008). Språk och kommunikation [Language and communication]. *Att läsa och skriva – forskning och beprövad erfarenhet.* Myndigheten för skolutveckling. Stockholm: Liber.

Lind, U. (2010). *Blickens ordning: bildspråk och estetiska lärprocesser som kulturform och kunskapsform* [The order of the gaze: visual language and aesthetic learning processes as a form of culture and form of knowledge] [PhD Thesis, Stockholms universitet].

Lindström, L. (2009). Estetiska lärprocesser om, i, med och genom slöjd [Aesthetic learning processes about, in, with and through crafts]. In Höglund, C.-M., Reuterstrand, S., & Wigerfelt, C. (Red.), *Krut - Kritisk utbildningstidskrift,* (133/134), 57-70.

Lindström, G., & Pennlert, L-Å. (2016). *Undervisning i teori och praktik - en introduktion i didaktik* [Teaching in theory and practice - an introduction to didactics]. Fundo förlag.

Lundborg, G. (2019). *Handen i den digitala världen* [The hand in the digital world]. Stockholm: Carlssons Förlag ab.

Marner, A. (2005). *Möten och medieringar: estetiska ämnen och läroprocesser i ett semiotiskt och sociokulturellt perspektiv* [Meetings and mediations: aesthetic subjects and learning processes in a semiotic and sociocultural perspective]. Fakultetsnämnden för lärarutbildning, Umeå universitet.

Mills, K. A. (2016). *Literacy Theories for the Digital Age: Social, Critical, Multimodal, Spatial, Material and Sensory Lenses. New Perspectives in Language and Education.* Queensland University of Technology.

Mäkelä, E. (2011). *Slöjd som berättelse – om skolungdom och estetiska perspektiv* [Craft as a story - about school youth and aesthetic perspectives] [PhD Thesis, Umeå universitet].

Pink, S. (2021). *Doing visual ethnography* (Fourth edition). Thousand Oaks: Sage Publications.

Power, J. R., & Sorby, S. A. (2021). Spatial development program for middle school: teacher perceptions of effectiveness *International Journal, 31,* 901–918.

Prop 2009/10:89. *Bäst i klassen - en ny lärarutbildningm* [Best in class - a new teacher education]. Regeringskansliet: Stockholm.

Rose, G. (2016). *Visual methodologies: an introduction to researching with visual materials* (4th edition). London: Sage.

Selander, S., & Svärdemo-Åberg, E. (2009). *Didaktisk design i digital miljö - nya möjligheter för lärande* [Didactic design in a digital environment - new opportunities for learning]. Stockholm: Liber förlag.

Selwyn, N. (2017). *Skolan och digitaliseringen - blir utbildningen bättre med digital teknik?* [The school and digitization - is education better with digital technology?] (L. Kollberg, Övers.). Göteborg: Daidalos AB.

SND; *Fotogrammetri; En guide till god hantering*_2019-10-29.pdf. [Photogrammetry; A guide to good management]. Accessed 25th of November 2023: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjk7KaYj9-CAxX9avEDHSVjAPcQFnoECA0QAw&url=https%3A%2F%2Fsnd.gu.se%2Fsites%2Fdefault%2Ffiles%2Fpage%2FSND%253B%2520Fotogrammetri%253B%2520En%2520guide%2520till%2520god%2520hantering_2019-10-29_0.pdf&usg=AOvVaw3pd47r7njGodkkojtAqrGW&opi=89978449

Skåreus, E. (2014). Bilder i forskning – visuella metoder, konstbaserad forskning & fallstudier [Images in research – visual methods, art-based research & case studies]. *Tilde, skriftserie, nummer 2/2014*. Institutionen for estetiska ämnen, Umeå universitet.

Sofkova Hashemi, S. (2019). *Vilka elever har nytta av olika verktyg? Hur tar jag som lärare hand om de nya verktygen i klassrummet?* [Which students benefit from different tools? How do I as a teacher take care of the new tools in the classroom?], RISE Interactive Göteborg Studio. Accessed 31st of May 2022: https://www.youtube.com/watch?v=SlA27E_2DXs

Säljö, R. (2021). Från materialitet till sociomaterialitet: Lärande i en designad värld [From materiality to sociomateriality: Learning in a designed world]. *Techne A, 28*(4), 193-208. https://doi.org/10.7577/TechneA.4736

The Swedish National Agency for Education [Skolverket]. (2015a). The national evaluation of visual art education in compulsory school, 2015 [Sw. *Bild i skolan. En nationell ämnesutvärdering i årskurs 6 och 9* (NÄU-13). Rapport 423, 2015.].

The Swedish National Agency for Education [Skolverket]. (2015b). Image, music and crafts in primary school. A summary analysis of the national subject evaluations [Sw. *Bild, musik och slöjd i grundskolan. En sammanfattande analys av de nationella ämnesutvärderingarna* (426)]. https://www.skolverket.se/publikationsserier/rapporter/2015/bild-musik-och-slojd-igrundskolan

The Swedish National Agency for Eduation [Skolverket]. (2020a). The situation assessment of The Swedish National Agency for Education [Sw. *Skolverkets lägesbedömning*]. (RAPPORT 2020:1), 100. Accessed 2nd of February 2022: https://www.skolverket.se/publikationsserier/rapporter/2020/skolverkets-lagesbedomning-2020

The Swedish National Agency for Education [Skolverket]. (2020b). Artificiell intelligens i skolan kräver ökad insikt hos lärarna. (Text by Marie Utterberg Modén, Martin Tallvid och Johan Lundin). Accessed 30th of July: https://www.skolverket.se/skolutveckling/forskning-och-utvarderingar/artiklar-om-forskning/artificiell-intelligens-i-skolan-kraver-okad-insikt-hos-lararna

The Swedish National Agency for Education [Skolverket]. (2021a). Changes in the introductory parts of the curriculum – Compulsory school, preschool class and after-school center [Sw. *Ändringar i läroplanens inledande delar - Grundskolan, förskoleklassen och fritidshemmet*.]

The Swedish National Agency for Education [Skolverket]. (2021b). Commentary material for the syllabus in visual arts. Compulsory school [Sw. *Kommentarmaterial till kursplanen i bild. Grundskolan*.] Accessed 22nd of February 2022: https://www.skolverket.se/publikationsserier/kommentarmaterial/2021/kommentarmaterial-till-kursplanen-i-bild---grundskolan?id=7830

The Swedish National Agency for Education [Skolverket]. (2022). *The Curriculum for Compulsory School, Preschool Class and School-Age Educare*, Lgr22 [Sw. *Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011*, Lgr22]. Skolverket: Stockholm.

The Swedish National Heritage Board [Riksantikvarieämbetet]. Immersiv teknik för immersiva upplevelser [Immersive technique for immersive experiences]. 15th April 2021. Accessed 23rd of July 2023: https://www.raa.se/museer/publikt-arbete/digital-formedling/god-praxis-for-immersiva-upplevelser/immersiv-teknik-for-immersiva-upplevelser/

The Scientific Council [Vetenskapsrådet]. (2017). Good research practice [Sw. *God forskningssed*]. Accessed 30th November 2021: https://www.vr.se/download/18.2412c5311624176023D25b05/1555332112063/God-forskningssed_VR_2017.pdf

Tombro, M. (2016). *Teaching Autoethnography: Personal Writing in the Classroom.* Tombro & Open SUNY Textbooks.

Wijntjes, M. W. A., Volcic, R., Pont, Sylva C., Koenderink, Jan J., & Kappers, Astrid M. L. (2009). "Haptic perception disambiguates visual perception of 3D shape". Accessed 23rd April 2023. 10.1007/s00221-009-1713-9

Willermark, S. (2018). *Digital Didaktisk Design - Att utveckla undervisningspraktiken i och för en digitaliserad skola* [PhD Thesis No. 13, Informatics with Specialization in Work-Integrated Learning, University West]. http://www.divaportal.org/smash/get/diva2:1174749/FULLTEXT01.pdf

OTHER REFERENCES:

Interview with 3D technician Joacim Harrysson, HDK-Valand, 18th of October 2021 by Dan Tommi Hildén.

Hippocampus - 3D Model by DanTommi (@DanTommi) [9d1f1ff],): https://sketchfab.com/3D-models/hippocampus-hpe103a-9d1f1ffe2cf249ba8e2c0a3f293028bc

From 'tool' to 'collaborator': Digital 3D modelling as a catalyst for new aesthetic practices – A study of student teachers' education in visual arts

Mie Buhl & Kirsten Skov

INTRODUCTION

The renewed interest in digital programming and computational thinking in Nordic education offers fresh opportunities for visual arts teacher education to engage with contemporary artistic practices (e.g., Andersen et al., 2022). Still, access to these opportunities may be associated with certain reservations about digitalisation among practitioners in a subject traditionally linked with analogue means for art making and the promotion of sensuous experiences as a core identifier. Why spend even more time on digital devices, which are already a time-consumer embedded in every aspect of our daily lives 24/7? Why not make the visual arts classroom a technology-free zone where bodily contemplative interaction with physical materials offers an escape from a digitalised environment and hence a space for potential personal growth? The short answer is that education is about being in and tackling reality, rather than building a fence against it. Further, visual arts hold the potential to explore the implications of technology by using it both as a means for art-making practices as well as addressing it as a theme for challenging our assumptions about what it means to live in a digitalised world.

A critical discussion on how to deal with digitalisation in all its transformative aspects is relevant and necessary – also in the field of visual arts education. Yet, visual practices based on principles from another field of knowledge, namely computer science, pose a challenge for art that is interesting to pursue. Art is inherently characterised by exploring and questioning phenomena in society – observing the unobservable aspects of sociality (Luhmann, 1993) – and by seeking and exploring ever new forms of expression and communication. Thus, in this article we do not want to discuss whether or not, but rather what can be gained from doing digital coding activities in the visual arts classroom based on two very practice-oriented, but also potentially professionally innovative questions: 1) how does an art practice of digital coding and construction provide the artist with new forms of experience through the production process; and, 2) which new aesthetic qualities emerge from programmed art? These questions relate to all artistic practices that involve coding activities, although this article limits the discussion to digital 3D modelling as a form of sculpture.

This article takes its point of departure in the assumption that digital coding as a means for art-making is epistemologically and ontologically related to practices of conceptual art. As the conceptual artist develops an idea, creates a 'recipe' for a work that comes alive in the encounter and interaction with an audience, so does a 'digital coder' produce a recipe for the computer to execute and make available for interaction with a user (Buhl, 2019).

The conceptual art-making process is related to planning based on an idea rather than the execution process of manual material manipulation. Let us take sculpting as an example of a process of manual material manipulation. When we enter the art classroom and start making an analogue sculpture, we are provided with clay and clay carving tool to start a modelling process. The modelling process with clay provides material resistance as the dehumidification process commences as soon as the clay is freed from plastic and gradually begins to dry out. The artmaker must work with the clay and use the motoric skills of the hands to model the material. This proceeds until a certain point when the softness of the clay has diminished, and the clay material acquires a hardness where a clay carving tool is needed to make new changes. At this point, the artist must also ensure that the ongoing dehumidification process is as uniform as possible to avoid cracks developing in the object under preparation. The further process moves towards total dehumidification of the clay object and a final burning. This is an example of a classic process that takes place in the visual arts classroom, along with the associated techniques needed to produce a 3D object by manipulating a physical material. Other soft moulding materials such as plaster or papier-mâché represent a repertoire of manual skills to be performed during the making process.

Yet, modelling a 3D artefact via computer is a completely different story: the material (digital) is different, the skill requirements are different, the processing from moulding to printing – or not – is different. These are processes to be discussed as a small part of a wide repertoire of digital art practices of tangible and intangible digital art which are becoming an increasing element of contemporary art and thereby a matter of didactics and pedagogy to address in visual arts education.

Thus, the purpose of this article is to discuss how digital coding and construction may provide new practices in visual arts education. The discussion is based on a study of digital 3D modelling practices performed by student teachers in visual arts. The aim is to reveal potential new aesthetic qualities emerging from an attempt to merge practices from two different epistemological paradigms: visual arts and computer science (Buhl, 2019). Another aim is to contribute to the discussion about how digital coding and construction can become a relevant part of a contemporary teaching subject in teacher education. In this article, the discussion draws on a Danish study framed by a national initiative to generally improve technological comprehension in teacher education and a subject-specific Nordic collaboration exploring digital 3D modelling in art teacher education (Buhl & Skov, 2021a). At the outset, regarding the site-specific modelling of artefacts for an urban environment the Danish study drew insights from processes of sculpting and installations within the arts.

Accordingly, the study contributes partly to the discussions on ongoing currents in the Nordics about implementing technological comprehension, computational thinking, and programming in education from the perspective of visual arts education (Andersen et al., 2022; Buhl & Skov, 2021a; Buhl & Skov, 2021b; Buhl & Skov, 2020), and partly to a subject-specific investigation of how digital technologies impact the learning content in visual arts education. The latter is the focus of this article.

The theoretical framing of visual arts education based on Danish developments

The current wave of digitalisation in the Danish education system affects the teaching subject of visual arts education and the education of future teachers. Working with digital image-making in visual arts education in Denmark is not new because images provided by computing have formed part of the curriculum for grades 1–9 of compulsory school since 1991 (UVM, 1991) and of visual arts teacher education for grades 1–9 of compulsory school since 1992 (UVM, 1992). As digital technology development has progressed, the means for art-making have varied from the earliest examples in the late 1980s (e.g., Skov, 1988) to the emergence of digital applications in the 1990s to 2010s such as Photoshop and Paint that enhanced and simplified the digital image-making process for a larger group of users (e.g., Buhl 2002; Flensborg, 2002; Rasmussen 2017). In many ways, this positioned the digital production process as a matter of being able to handle the digital image-making tool by activating a cursor on icons that were aligned with analogue tools such as 'brush', 'pencil', 'colour' and 'paint on the screen'. Towards the end of the 2010s, when the effects of even more advanced algorithm-driven communication had become evident, e.g., as an accessory for 'filtering' reality on social media, attention more strongly shifted to not just using but also understanding how digital technologies work, which in some ways has revitalised the goal that more people should be able to code and construct with a computer to be able to generate images.

The development re-actualised the difference between creating images by hand and the use of digital codes to create images. Digital literacy raises a question about cognition and aesthetic education in the subject. Will programming mean that the visual arts subject will train programmers instead of artmakers? Will the training of digital skills take all of the focus at the expense of contemplative processes of creation in physical materials? Will the purpose of technology-based image-making mean learning to understand how technology works rather than being able to ask curiously critical questions about programming and algorithms as phenomena of the world around us?

The somewhat polemic contradictions between technology and art-making express a real concern that the unreflective introduction of digital programming into the school's visual arts teaching could lead to a professional practice whereby visual arts activities using programming become helpers for developing computer science skills. This scenario could become a reality if digital material is seen as a contrast to the subject's analogue materials, such as clay, paper, papier-mâché, plaster, paint and chalk. It could become the reality if programming is practised in a socio-cultural context, detached from the visual arts curriculum and without discussing the aesthetic implications of making, for instance, 3D objects by means other than the well-known plastics. We argue that we need a reconfiguration of the means for art-making and aesthetic learning.

A new understanding of materiality

Visual arts education has a tradition of understanding material as a physical entity available for human processing: 'I' mould the clay, 'I' draw on paper, 'I' paint on canvas (Buhl, 2019). However, since the 1990s digital processing has (e.g., Manovich & Arielli, 2023) simulated many of these human-based activities, changing the role of the artmaker into a 'digital operator' rather than a 'manual maker'.

A perspective emerged in research that challenges the human perspective as a starting point for professional practice, which we will attempt to relate to an art practice. The anthropologist Latour (2005) calls the human perspective an *anthropological asymmetry*. By asymmetry, he meant that we understand everything we do in terms of human will and action. If we apply that to visual arts, for example, this means that the making of a picture, a drawing or a sculpture are expressions of human intention.

Latour was critical of the idea that the human being is the only actor. Instead, he suggested looking at the whole process of – in this case, the art-making process – as a patchwork of many human and non-human actors. He explained that everything which makes a difference is an actor (Latour, 2005, p. 71). This would mean that brushes, sketches and clay are actors on a par with the body, space, time, curriculum models, mobile phones, chairs, tables, subject discourses and whatever else exists that helps to organise a concrete art-making practice. Human and non-human actors are networked with us: the table we are standing beside and the space we enter, the things we say and do are driven by a long tradition of similar practices using language and symbols. Latour developed the idea for his actor-network theory by following processes in which professionals carried out their knowledge practices. He thus showed that professionalism is in the making rather than a fixed entity. He described the notion of actor-network through an example of a group of biologists working on mapping plant diversity in a forest standing in the Amazon jungle and emphasised the many and varied material practices and activation of symbols and signs leading to the result (Latour, 1999). Latour used this example to argue that results of scientists' work are not simply a human-driven process. The same can be argued about the art-making process. The knowledge that emerge as an effect of a series of dynamic actions with clay, computers, software, artistic discourses, etc. echoes past practices of investigations of a similar nature. Latour thus broke with a subject-object dichotomy, in which it is only the intentional actions of - in our case - the art maker that create knowledge, and equate with human and non-human actors as necessary participants in the art-making practice. Drawing on Latour, professionalism is in 'becoming' through art making practices.

We suggest taking this approach to understand art-making practices in education. The teaching subject of visual arts is in 'becoming' as meaning-making practices involving human as well as non-human actors.

Educational research has been inspired by Latour's actor-network theory (ANT). British educational researchers Fenwick et al. (2011) claimed that ANT is an opportunity to rethink and intervene in established pedagogical practices and thereby 'reframe' the taken-for-granted ways in which education is understood. The authors argued for pedagogical practices as socio-material processes. They exemplified the materialities of the school as continuous flows of pedagogical events. This flow includes, for example, clothing, timetables, access codes, pencils, windows, stories, plans, chewing gum, desks, electricity and light. These materialities are not considered as separate objects, but as collections of materiality patterns, also called *hybrid assemblages*. The materiality patterns are continuously changing and include human and non-human energies that are constantly combining into assemblages and dissolving away from other assemblages (Fenwick et al., 2011, vii).

Visual arts are practised through, for example, clay, paint, paper, art discourses, tablets, bodies, classrooms, didactic models, schedules etc., that offer different forms of participation. These forms of participation become part of the visual arts discourse in art teacher education for a while and may spread to other teacher training institutions. There is a continuous practice of 'doing' that is attributed meaning and it is these processes that can be studied and understood as a form of knowledge assemblages. The purpose of the socio-material perspective is not to devise new theoretical categories but to see new possibilities in the way in which the current visual arts education is unfolding.

The fact that researchers point to the non-human as something that *acts* may seem quite speculative and provocative, not least in relation to a subject where human expression is so much at the centre of professionalism. Fenwick et al. state, for example, that a subject is not separate from an object, or that a knower is not separate from knowledge, and that a learner is not necessarily a human being. The mentioned authors (2011) observe that something other than humans' seems highly relevant at a time when a non-human actor – artificial intelligence (AI) – not only acts but acts in a way that is difficult to distinguish from human actions. The rapid development of Generative Pre-trained Transformer (GPT) technology may even be an indicator of a break from the one-sided view that all action is the result of human intent, showing us other non-human actors around us. This approach provides us with a perspective on digital technologies and programs as materialities entangle with other materialities in art-making practices. However, the authors' aim is not to marginalise the human being, but to draw attention to the fact that learning and education are not only social or personal processes. One must imagine that learning processes take place in an entanglement of materialities which create a professional learning practice. In other words, it is not only what the educator has imagined will happen or what they see the student teachers doing that constitute the professional practice of a visual arts education. Different materialities intertwine and make up a professional practice driven by the relationship between the energy flow of the different materialities.

We suggest that the socio-material perspective on how professional learning proceeds provides a slight twist which forces us to change our perspective on our own practice, and not to discard everything that is not about personal expression. The perspective offers an opportunity to understand that what is unfolding around us is not only driven by intentional actions. In an educational setting, this makes for a change of perspective as we as educators are used to focusing on students' cognitive and aesthetic development. Still, Fenwick et al. (2011) argue that the perspective can help us to recognise nuance and understand how learning practice unfolds through "visible activity and invisible infrastructure, forms and purposes of knowledge activity, and different combinations of materials, meanings and energies" (Fenwick et al., 2011, p.14). We come to look at our own teaching practice with fresh eyes.

A socio-material perspective on aesthetics alters the view on aesthetic learning processes. From being seen as a sensuous and intentional process controlled by the human actor's strive for the sublime, the image-making process now becomes a social and material interaction between non-human and human actors, where meaning-making emerges from this interaction. This also provides new perspectives for the critical discourse in the teaching subject aiming to reveal power structures articulated through visuality as coined by scholars in the visual educational field (e.g., Gude, 2004; Kiefer-Boyd, 1996; Pedersen, 1990) and with the integration of a visual culture perspective (e.g., Duncum, 2010; Freedman 2003; Illeris et al., 2004). The socio-material aesthetic offers an entanglement of human and non-human agency and hence an opportunity for the teacher to plan and practise based on a renewed perspective on what is at stake in the classroom. As visual practice is argued to be socially critical and culturally intervening, this critical disciplinary perspective is also highlighted as a necessity in visual arts practice in the context of the revitalisation of digital programming in visual arts education (e.g., Knochel & Patton, 2015; Knochel, 2016a; Knochel, 2016b). Knochel and Patton (2015) see visual arts as a crucial contribution to the debate on the role of technology in society. They thus see programming as a theme for visual arts practice, rather than as a visual arts practice. However, a discipline-renewing perspective on visual arts practice holds wider potential than using programming as a theme for digital empowerment (Buhl, 2019). Contemporary art offers a shift in focus from the production of analogue objects as works (e.g., a painting or a sculpture) to the development of concepts that are only activated as works in the concept's involvement of an audience (Bourriaud, 1995).

From this perspective and in line with other material practices, coding practice would be a conceptual and material practice. Knochel and Patton (2015) explain that software is not a tangible matter, and that it is the fact that it can perform code actions that constitutes its materiality. Namely, it is a 'material system of activity' consisting of software, user interface, and the code language used to connect the elements, which is performed through programming. Viewing materiality as something that has agency – that it acts – provides an understanding of what coding is as the new thing in visual art, yet it also provides a new perspective on analogue art-making. In this view, art-making is not the result of a human being having an intention, deciding and translating it into an art artefact. In this new view, art-making is instead a process of negotiating meaning between different materialities (clay, table, clay carving tool, water, symbols, discourses, body, code language etc.) and turns the process of aesthetic cognition into a system of social and material actions (Knochel & Patton, 2015, p. 30).

While this practice has always been the case, the understanding of what goes on in an art-making process has, with the challenge from programming, been given a new perspective where the human actor is not the exclusive one in focus. The focus is now also on non-human actors and how these actors are involved in the way meaning is created. The perspective on art-making practice as an activity system of social and material processes equates digital materialities with other materialities, and the production of a clay object can be understood with the same socio-material logic as a digital object. From this perspective, the processes of coding for digital 3D modelling are not add-ons to existing areas of competency but become an integral part of the subject that can contribute new aesthetic qualities of expression and generate new meaning. Herein lies a subject-renewing potential for the visual arts subject (Buhl, 2019).

Knochel (2016b) posited from an actor-network perspective that image-processing programs are non-human didactics because they instruct students on how to perform visual actions. Inspired by Latour's (2005) actor-network theory (ANT), his example adopted a broader perspective regarding how learning situations may be approached as a complex of social and material agency. On one hand, image-processing programs simulate recognisable analogue tools; on the other, they offer new and different production possibilities such as countless layers, multiple-form manipulations and endless editing possibilities without destroying the material basis. Technology offers a new materiality and thereby new opportunities for art productions that might surface in situations of practice. Following the perspective of Knochel (2016b), image-making could be approached as a social and material process with a new set of possibilities for visual production where digital technology is a co-productive partner. An art-making class with digital 3D modelling performed in a physical and online environment forms a "continuum of materials, ideas, symbols, desires, bodies, natural forces, etc. that are always active, always reconstituting themselves" (Fenwick & Landri, 2012, p. 3).

Fenwick and Landri (2012) suggested that the well-established dichotomy between human intentionality and non-human objects must be overcome for a fuller understanding of learning processes. They also suggested that the agency of digital technology and other materialities may be approached with the term hybrid assemblages to describe how learning emerges from a continuous social practice of different materialities of 'doing' to which meaning is attributed rather than by an approach drawing on a 'human-using-tool-metaphor'. Our art-making practices are not ours, but

Design for teaching visual design

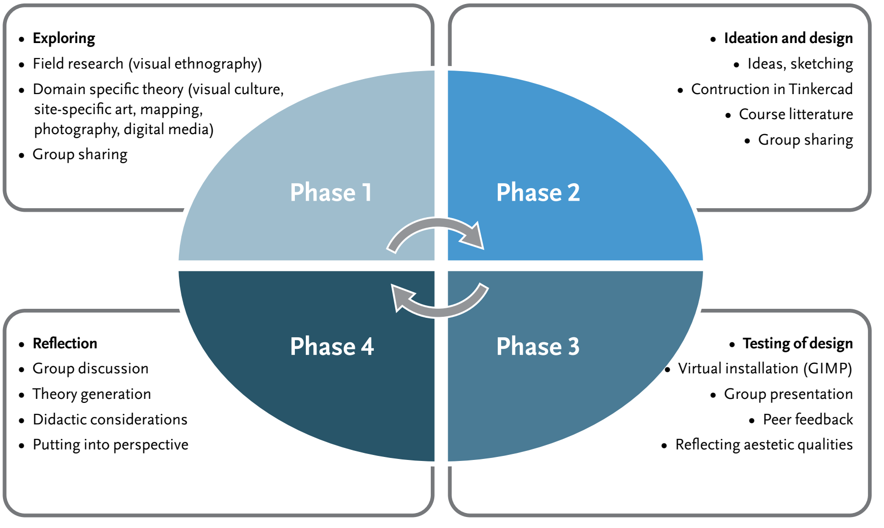


Fig. 1. Design for teaching visual design of 3D modelling developed by Mie Buhl, 2020.

something in becoming together with non-human actors.

METHODOLOGY FOR THE EMPIRICAL STUDY

Curious to explore how a social material approach might reveal new relations between materiality and meaning-making, we conducted a study of student art teachers engaging in creating site-specific objects by coding and construction activities with TinkerCad (a cost-free application). The study was designed as an integrated part of the ordinary art curriculum with a duration of 8 hours in the autumn of 2020 (Buhl & Skov, 2021a). Two classes of student teachers participated. They were informed of the purpose of project, their part in the project and the roles of the teacher and the researcher prior to study initiation. They all signed a declaration of consent that followed ethical guidelines of anonymity, data management and the opportunity to redraw from the project. The study was based on the principles of a visual design process (Fig. 1) that is generic and can be adapted to different art-making practices. Thus, the model served as both as a structure for teaching visual arts and a model for design-based research (Amiel & Reeves, 2008). A particular research interest was how 3D modelling, typically associated with the artisanal manipulation of physical materials such as clay, would change (or not) when the modelling was performed using digital coding and construction. We were interested in learning about these situations of making: would they generate unexpected new practices, would new aesthetic principles for processes of sculpting in the context of 3D emerge, would new critical insights about site-specific art be obtained?

The visual learning design was organised as a digital 3D-modelling assignment using the software applications TinkerCad and GIMP. The empirical data consisted of teaching plans and materials, observations (2 x 4 hours) such as photos and field notes, and oral and written student evaluations.

Further, our co-researching along with peer discussions provided a contextualisation of our observations. The empirical data from the intervention phase were approached and analysed from two perspectives. The first perspective focused on how digital technology was entangled with other materialities in the student art teachers' practices of meaning-making (Fenwick & Landri, 2012). This indicated how the designs were adopted as a means for art-making. The second perspective concentrated on how the students approached and engaged with the learning designs as curriculum. This revealed how the art-making practices were negotiated in the collaborative processes and how the students and teacher attributed meaning to integrating principles of computing into art-making (digital 3D modelling). We present our empirical findings in connection to the four phases (Fig. 1).

Framing the art-making practice

The visual learning design for the students' digital 3D modelling was framed by principles of exploring and designing and contained the following elements:

Phase 1:

1. An on-site inquiry in an urban environment aiming to improve architectural and aesthetic qualities and ensure experiences with urban architecture through photo documentation and the sketching of ideas.

2. Introduction to site-specific art, digital 3D modelling in architecture, art, and design in general, as well as to the Danish visual artist Morten Modin and his artistic processes exploring digital 3D modelling in terms of site-specificity, materiality and scaling (Figs. 2, 3, 4).

Phase 2:

3. Introduction to and experimenting with TinkerCad.

4. Design of digital 3D modelling prototypes for the urban site and testing the visual aesthetics in relation to the code blocks, programming and construction produced by student teachers.

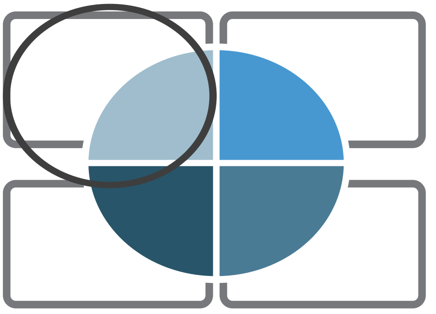
Phase 3:

5. Use an image-processing app (GIMP) to place the prototype in the selected urban placement and provide a feedback session.

Phase 4:

6. Reflection on digital 3D modelling in art-making. Reflection on how to implement 3D digital modelling in school practices.

IMAGE-MAKING ENTANGLED IN THE DISCOURSE OF TWO DIFFERENT PARADIGMS



Phase 1: Exploring and searching

After an introductory session on digital technology in visual arts education, the student teachers were presented with the task of creating a 3D modelling assignment. They were tasked with creating a *visual and virtual manipulation of a site-specific public space*. The art-making assignment was to represent the three phases of a visual design:

1. Choose a site that you want to transform a better place by adding 'a certain quality'.

Fig. 2. Site-specific work, Jernbanemodellen, Kunsthal Nord S1, by Morten Modin 2018.

Fig 3. Site-specific work, Jernbanemodellen, Kunsthal Nord S1, by Morten Modin 2018.

Fig. 4. Spielen, mixed materials, 100 m^2, Kunsthal Kongegaarden, Morten Modin, 2021.

Fig. 5. CBS-Kilen (the Wedge) – a public space and traffic connection point for bicycles between different university campuses in Frederiksberg in the centre of Copenhagen and surrounded by a campus building (CBS) and a shopping mall (Frederiksberg Centre). Photo: Kirsten Skov

2. Design a prototype in the cost-free 3D-modelling programme TinkerCad.

3. Create a virtual placement by using GIMP (a free, open-source photo editor).

The observations showed while the student teachers were generally open to the assignment, they also showed some anxiety: "How cool", "how exciting", "sounds difficult", "I wonder if I can do it...". The combination of working site-specifically and with digital 3D modelling pushed them into a challenging situation that called for various art-making skills.

The students were then introduced to the first phase entailing instructions on how to work site-specifically with visual manipulation in an urban space, drawing attention to the intersection of architecture and sculpture. Here, exemplifying site-specific art works from different geographical locations as well as representing prominent works in the history of art were used as both a theoretical framing and inspiration for the upcoming digital modelling.

The preparation for field studies on location was a scaffolding of how to conduct the inquiry. The teacher students were instructed to start from a place/site that could be made an object to rethink, reformulate or improve place by adding a certain quality that the place lacks. The reformulation could be made by commenting on/drawing attention to something, creating a functional or poetic solution, or working with interior design/decoration/aesthetics. The exploring was to be performed at the location and the chosen focus was to be described and documented visually by various sketch proposals prepared in drawings and possibly as small spatial cardboard models.

The students conducted the exploring in a given space within a radius of a maximum 1 km from the Copenhagen Business School CBS-Kilen/Carlsberg in the centre of Copenhagen city (Fig. 5) where they could select

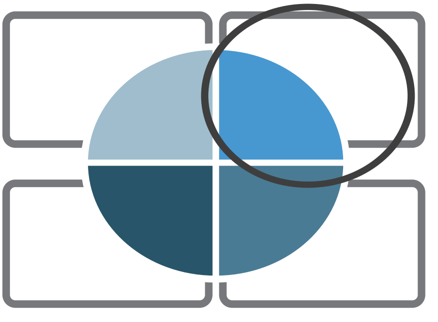
Fig. 6. View from the CBS-KILEN. Photo: Kirsten Skov.

a site/location they wanted to work with. By adding this spatial framing, they were scaffolded in the process.

Moreover, they were instructed on how different means for exploring would help with focusing and producing material for the activities back on campus. They were encouraged to take photos, video, sketches, audio recordings etc. to capture the issue at the location in question, discuss it with peers, take notes, and to make initial drafts of ideas for a manipulation at the mentioned location. The fact that they were to practise their inquiry in a public space to complete their field studies exceeded some students' personal limits of behaviour and some distanced themselves from the embodied experience of the site; others were triggered to have a playful presence and become absorbed in the situation. The students reacted with embarrassment as well as excitement, and the agency of the physical space was evident.

One group chose to focus on making a solution to the consistent overloading of parked bikes (Fig. 6) in and around the area of CBS-Kilen and make a practical as well as an aesthetic proposal.

Phase 2: Ideation and designing



The next phase entailed the practice of ideation and designing. The students were instructed to ideate and design a virtual prototype illustrating the reimagining of the site-specific change. To be able to realise the virtual prototype, the students were introduced to the use of an application for digital construction activities. TinkerCad is an online 3D modelling program used for designing for 3D printing. The program is promoted as intuitive and easy to use, even in early schooling. The programming of a 3D object is done using code blocking, which has similarities with, for example, LEGO or Minecraft. The students were instructed on how to use TinkerCad. Becoming acquainted with TinkerCad was facilitated as a lab for the technical exploring of possibilities as well as taking the first steps in ideation and design. Further, the students were instructed to construct a common professional visual arts and technology glossary to support awareness of a visual arts perspective and a technological comprehension perspective as well as possible crossovers between the two disciplines, such as displacement, principles of construction etc.

While working in TinkerCad, the students were encouraged to investigate the possibilities of changing the code blocks and the resulting effect on the aesthetic visual output. After several experiments with different shapes, repetition, constructing with holes, and respectively with or without transparency etc. in the prototypes, the students were encouraged to creatively reflect on the actions' impact on the constructed code and the visual expression. They were to analyse the code blocks and their function in the algorithm and to examine the effect of re-ordering the code and to assess whether some codes were more important than others. This was meant to establish coherence with technological comprehension in terms of code blocking and construction as well as contribute to a critical reflection on the pros and cons of using technology in art-making practices. To connect experiences from everyday fields, the students were asked to identify experiences similar to programming and construction such as Minecraft or LEGO.

The student teachers' process of acquiring TinkerCad, ideating and designing a digital prototype was approached in various ways. The educator shared with the students that this approach was new to her too, that she did not know everything about the program in advance, and that the application was a joint venture of exploring digital 3D modelling together. Simultaneously, she shared her experiences from testing the application herself and called for a function that can challenge the geometric figures the application is pre-coded to produce. The call to explore both the possibilities and limitations of using the application is typical of a visual arts discourse: the desire to challenge predefined possibilities of expression and experience. At the same time, this call for joint exploration was an invitation for the students to become both visual co-researchers and co-teachers of what 3D modelling enables in a learning context.

The students used both analogue and digital materials for sketching and modelling. They were encouraged to work in groups and use different media in the process. The use of analogue tools for ideation was familiar, whereas the digital tools were not. Encountering a new toolbox is one thing, but encountering a scientific paradigm that follows a logical principle which contrasts with the logic of artistic representation is quite a big thing to take in. The process of ideation and designing merged from assemblages of computers, papers, art discourses and computer science discourses.

A group of three students started working on and testing TinkerCad. They had missed participating in phase 1 and thus had not yet found the place for which they would design an object. After working with TinkerCad for a while, they left the room to find the space they wanted to work on. The group took a technology starting point and explored TinkerCad before starting to work with the art-making, thus breaking with the design of the learning process. The affordance of TinkerCad appealed to them, they were more challenged by engaging in the art-making part. This group worked exclusively digitally. Another two-person group began by looking for inspiration on the Internet. They used the screen to search

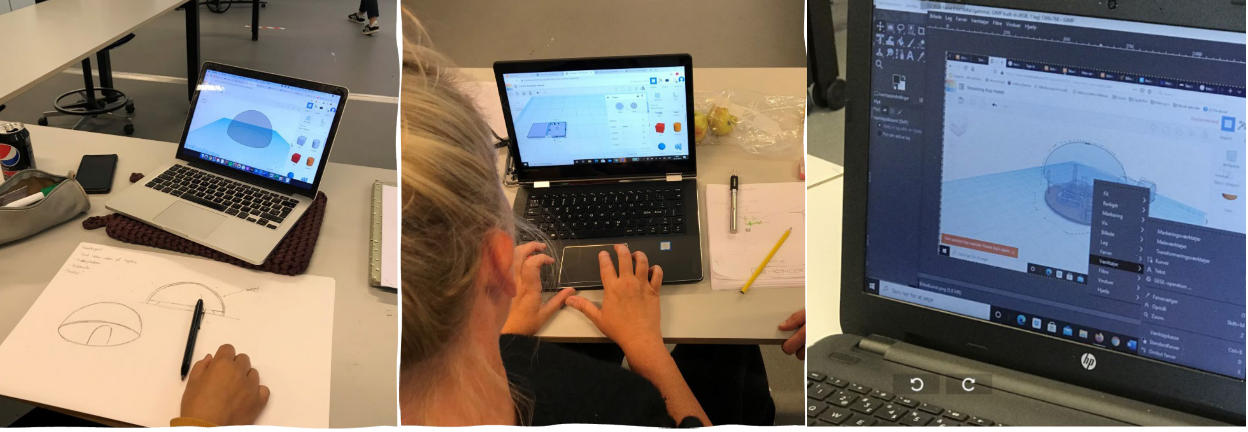


Fig. 7. Ideation and designing activities. Photo: Kirsten Skov.

and took notes next to it with paper and pencil. A third (three-person) group started by getting black and white card stock paper. They then left the room to work in another environment. A fourth group picked up white sketch paper and started to do experiments with TinkerCad as the group members had tried the application at home and had prepared for the group work.

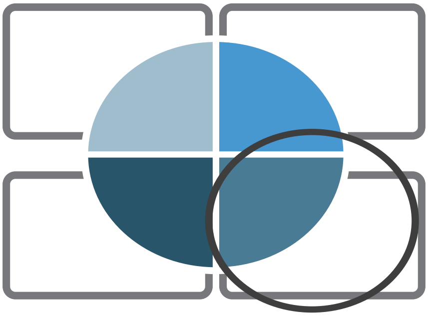
The groups approached the obstacles derived from unfamiliar coding operations by developing coping strategies, such as ideating on paper while one appointed group member transferred it to Tinkercad. In other groups, students used screens for the ideation process and discussed the different ideas within the group. There were also examples of students collectively discussing and ideating within the group, while one appointed group member transferred the ideas to the screen.

Overall, the exploration of the technical possibilities of TinkerCad was done individually, whereas the creative process with the site-specific object was worked out in groups. The screen attracted attention and the moment the working started on the screen the groups stopped talking to each other. The laptops controlled the organisation as well as collaboration, for example, the group process was interrupted when a laptop had to be charged.

Different approaches to the task could be identified. The groups were clearly challenged by the situation of combining the logics of a digital coding paradigm and art-making practice. They responded with a range of actions: some went in and out of the room, sent text messages, fetched paper, ate bananas, had coffee or took a break. The self-organisation allowed the groups to proceed at their own pace. At the same time, it encouraged 'procrastination' in terms of using TinkerCad and working on idea development. Procrastination is not unusual when engaging with creative processes and is more to be understood in terms of the relatively short time frame the overall project could allow to allocate to acquire a new means for art-making.

The group developing a solution for the storage of bikes around the CBS-KILEN area did both analogue and digital sketching (Fig. 8). They worked with the principle of transparency to maintain the area's lightness and openness, the principle of 'height' to resolve the need to store the many bicycles, and an organic form related to the cubic and rectangular buildings surrounding the place.

Phase three: Interventions



In phase three, the first prototype of the 3D-modelled object for the virtual manipulation of an urban space was to be tested.

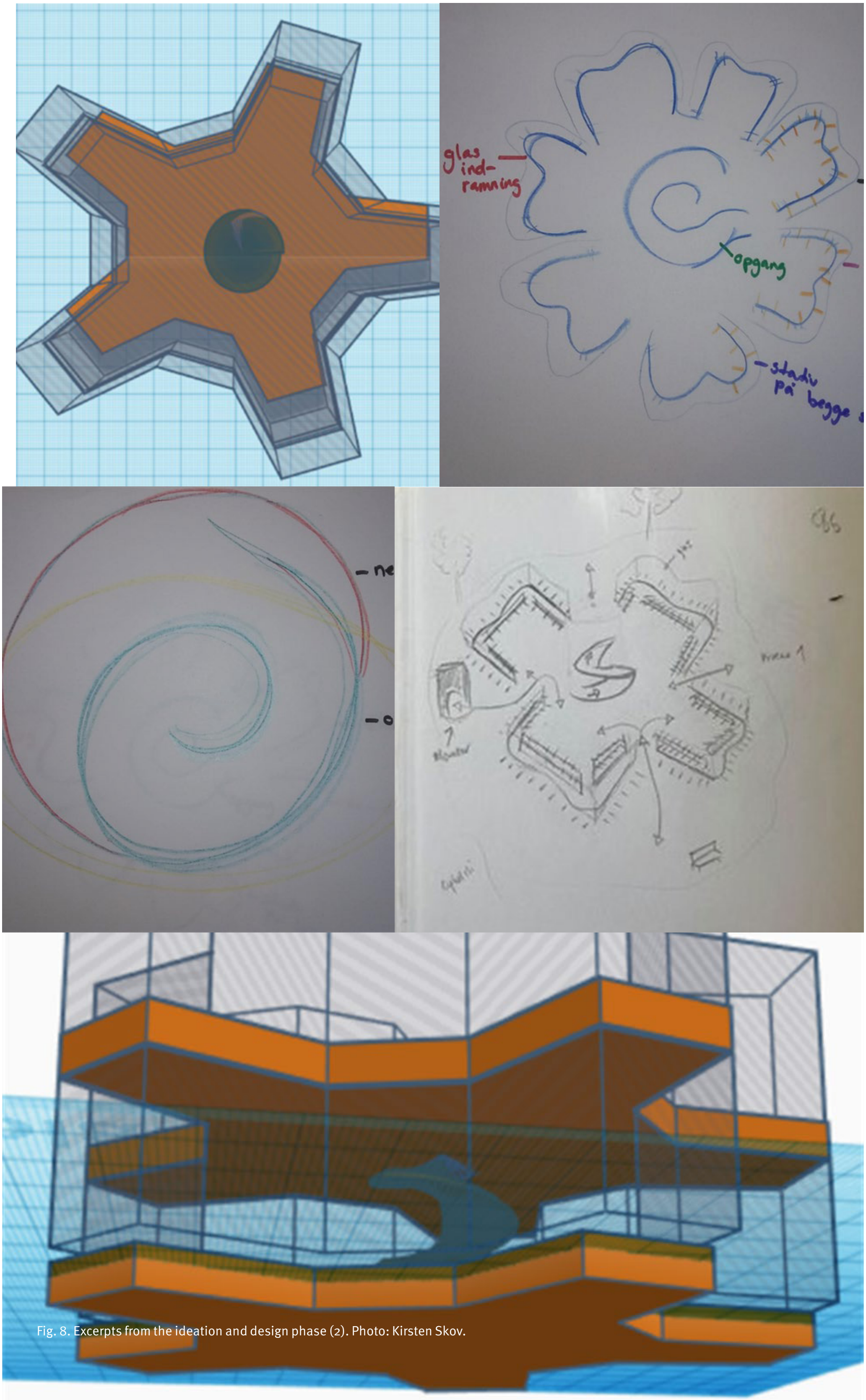


Fig. 8. Excerpts from the ideation and design phase (2). Photo: Kirsten Skov.

Fig. 9. Bike storage in context. Photo: Kisten Skov.

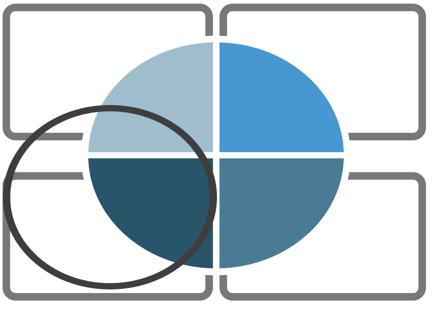
The students were requested to present their proposal by making a digital placement of the object in the intended context of the urban space. TinkerCad affords a 3D printing process and would allow for a tangible experience of the prototype. However, 3D printers in the typical academic institution have a print capacity for very small objects, which favoured a virtual solution in an image-processing program. The open-source editor GIMP was proposed. GIMP possesses the necessary functions for editing and transcoding between different image files, which was what the students required to place their solution virtually in context. Phase 3 was also where the idea, the aesthetic qualities of the model, and the model in context of the chosen location was presented to peers for critical and constructive feedback. Thus, the student teachers were instructed to prepare three different variations of a proposal for an object that they could present. They were to focus on the formal effects of 3D modelling, such as rhythm and repetition.

In preparing the presentation, the whole focus was on the computer screen. The objects in three variations drew on one concept. Computer technology provides these requested variations easily and rapidly, while an analogue production would be far more comprehensive. All groups were able to make a presentation of their objects, but not all could present the object in context. Even though GIMP is relatively simple to use, several struggled with the program. This shows that the ideas of simple and intuitive applications hold implications beyond pure technical operations. Rather, the entanglement of digital operations and culture, discourse, and situatedness impact how an application is approached. The bike storage group managed to place their virtual prototype in context (Fig. 9.). The object is placed on site and could give an impression of where and how the installation would be realised. Discussions of aesthetic qualities like size, material, surface, transparency were difficult to show by merging the object with the context in GIMP. Still, the oral presentation could elaborate and form the basis for discussions on the solutions.

The exercise in phase three invited experimentation and play with scale that is not 1:1 with the surroundings. When objects are either scaled up to be mega-objects and mega-formations or, conversely, mini-objects and mini-formations in the site-specific context, this gives rise to new ways of looking at the existing surroundings. The locations can be experienced as dense, present, intrusive, overwhelming, filled, manageable and intimate by objects that are large relative to the context – or the opposite, if the objects are small relative to the overall scale of the location. The 'odd' scale encounters can create new visual meanings and experiences.

Working with scale in a site-specific context requires students to make judgements about aesthetics, function, meaning, extent etc.

Phase four: Reflections



As part of the teacher education programme, the student art teachers are obliged to use their own art-making practice experience for pedagogical considerations in the perspective of their future profession as an art educator. The entangled practices of enacting art educational 'assemblages' such as digital and analogue material, bodies, spaces, visual culture, art, and computer science discourse etc. also involve an education discourse. These practices were involved throughout the phases, but in phase four they were addressed with a particular focus on how to articulate the agency of these social material entanglements. The students were required to distance themselves from their own situations of 'doing' and articulate new insights regarding 3D modelling. Notably, there was a focus on matters of the two paradigms art-making and computer science because connecting these paradigms is a profound change in visual arts education. Questions were thus posed addressing the experienced art-making practice such as the relationship between the constructed code and the created image expression. This included them analysing the code block used in TinkerCad and how these blocks functioned, and how they are created with programmable technology. Were some features or blocks preferable to others? They were also asked to compare the work with coding and construction with experiences gained outside class and to discuss the advantages/disadvantages of using digital technologies in design. How did they evaluate their 3D modelled object and describe its aesthetic qualities: Was it static or dynamic – still or inmoving? Was it an open and inviting model or did it have a more closed expression? Were the elements of the object organic, asymmetrical or more geometric? They were asked to reflect on 'shape', 'breaks', 'displacements' and 'principles of constructions and connections' and to outline a common glossary for the two paradigms visual arts and computer science.

It proved to be quite difficult for the students to understand the possibilities in TinkerCad for changing the code blocks and the resulting effect on the visual output as the students instead perceived it as 'just' a possibility of designing visual arts as opposed to being a matter of technological comprehension as well. Most students had never used a 3D modelling program. Further, it was their first real encounter with the concepts and perspectives of technological comprehension. The timeframe of about 8 hours determined by the overall project design did not leave them much space to reflect and feel in charge in the process.

THE EVOLUTION OF NEW AESTHETIC QUALITIES AND COLLABORATIVE PRACTICES DERIVED FROM DIGITAL 3D MODELLING

The study aimed to investigate digital 3D modelling as a mode of sculpting with respect to two questions: 1) how does an art practice of digital coding and construction provide the artmaker with new forms of experience through the production process; and 2) which new aesthetic qualities emerge from programmed art? The following outlines some findings from the study.

The art practice of digital coding and construction providing the artmaker with new forms of experience through the production process

The study revealed that it is difficult to integrate the logics of computer science and the art paradigm. For years, visual arts education has integrated digital media into artistic practice. Yet, this has largely been based on a tool metaphor by analogy with other artistic tools. Digitising artistic practice is nevertheless much more than adopting a new tool, and it must be considered how the agency of technology is connected to human agency in artistic practice. The TinkerCad software should be understood partly as an instructor and partly as a collaborator (Knochel, 2016b), although its use requires a paradigmatic logic derived from programming, deconstruction, and computational thinking, which offers the artist new possibilities if this paradigmatic logic is appropriated, adapted and accepted. Digital 3D modelling disrupts the linear logic associated with craftsmanship in analogue material such as sculpting processes. The transformation of physical material qualities into codes for an act of programming creates another material encounter; namely, the encounter with digital material. Digital material allows for multiple edits throughout the idea-development process due to the technology's lack of material exhaustion. Digital ideation can also interact seamlessly with the many ideation processes carried out on paper or cardboard, thereby expanding the method repertoire (Fenwick et al., 2011; Fenwick & Landri, 2012). The students' experience of crafting an object by physical material being replaced by a second-order command using a computer keyboard created a clash between the two paradigms of art and computer science. Adopting a coding paradigm – even though it was block coding – is very different from the manual manipulation of physical material. Modelling requires direct eye-hand coordination, and the material is altered by tactile pressure and motor interactions between material and body – human and non-human actors. The students experienced a new mode of 3D modelling where the motor skills shifted from manual sculpting to pressing the right computer key and responding to digital material feedback rather than physical material feedback from, e.g., clay.

The study hence revealed a diversity of meaning-making and collaborative forms between human and non-human actors – referred to here as a hybrid assemblage (e.g., Fenwick et al., 2011). Computer coding and conceptualisation in art show similarities in that both lead to a precept (algorithm/concept) executed by the computer on command and/or realised by the encounter with an audience. The conceptual art approach transforms the artwork from being a piece to be seen to an idea to be unfolded and realised.

The differences on the operational level, where the integration of coding practice with artistic practice adds to the complexity is one thing, while another is the differences in the paradigmatic discourses of the two disciplines. A key difference is epistemological: while the rationale behind computer science is problem-solving (e.g., Wing, 2006), the rationale behind artistic work is more to identify and expose the nature of a problem (Buhl, 2019). Integrating computer logic with the logic of art in visual arts education should be done on the terms of art when teaching visual arts. In the study, this manoeuvre caused problems for the students, partly because coding caused practical difficulties and partly because coding was perceived as unfamiliar to the subject.

We argue that by approaching digital 3D modelling from a social material perspective, coding practices can be integrated as part of the hybrid set of meaning-making practices that involve digital materiality as an actor. In this context, computer science offers a new repertoire of forms of expression, using data as a new material and applying computer science principles to design visual expressions, actions and narratives. The realisation of this, however, requires the calibration of the data science knowledge paradigm so that it can be accessed from and understood in an art context. The terminology for computer science (logical reasoning) and for visual arts (experiences of otherness) traditionally represent two divergent practices. Digital literacy in the visual arts can establish a 'common third' that is developed in the encounter between computer science and modern art practice (Andersen et al., 2022; Buhl 2019).

In sum, the study revealed that an encounter between art-making and coding raises issues of a paradigm clash between art-making practice and coding practice. We suggest that the clash may be overcome by engaging with a social material comprehension of the practice as an assemblage of meaning-making (the operational level) and engage in unfolding a conceptual art-making approach that is characterised by focusing on the ideation as the art-making act (coding) and the execution as the realisation of the concept (human- and/or computer-generated work).

New ways of judging aesthetic qualities emerge from programmed artistic practices

The study showed a re-organisation of artistic practices and provided new perspectives on the development of the aesthetic qualities of 3D models, as elaborated below.

Recurring experiments without exhausting a material's quality

Transforming an on-site bodily experience into a virtual format allows for recurrent experimentation with design elements. This can be done in interaction with a computer, e.g., by developing principles for editing, for exploiting the infinite possibilities for modifying a design, setting criteria for knowing when to stop experimenting, and transforming analogous aesthetic qualities connected with the 3D print (surface, texture, scale, volume). These are all actions performed in the 'digital interface construction phase' of a 3D artefact. Editing and principles for exploiting the infinite possibilities for ideas and changes to a design, as well as establishing criteria for when to stop experimenting, is an important art-making skill.

Multiperspective as an enhancement of spatial perception

The possibilities are endless to extend the experiments with virtual locations and explore multiperspectives and spatial issues without the costs associated with making a physical site-specific manipulation.

The gaze derived from the bodily experience of being and moving in a particular space such as CBS-KILEN is nuanced by the multiple perspectives offered by the virtual shift between the bird's and frog's eye view, providing an overview of the contextual interplay of existing components that together form an overall picture of a given space. Managing the many variations of components is an important artistic skill.

Scaling as a mode of spatial comprehension

Odd-scaling encounters can create new experiences and meaning-making. Scaling in site-specific contexts requires students' judgement about aesthetics, function, meaning and sustainability. The down-scaling of an existing environment and physical design such as CBS-KILEN enables a new intangible art-making practice on the screen. Understanding and judging the span of scaling possibilities is an important art-making skill.

Postponement of a physical materialisation as a stimulator of ideation

The bike storage group's design for CBS-KILEN was ambitious in terms of both construction (spiral shape) and surfaces (glass). The possibilities are endless as the limit to what can be constructed lies in the software application. However, the possibility to create and experiment digitally with a 3D artefact invites thinking that is bigger, more experimental, and playful because the ideation process is not limited to physical modelling, which is time-consuming and calls for manual skills and knowledge of materials. Yet, the quick option can prevent the designer from undertaking timely consideration and reflection. Material decisions based on a series of virtual samples and knowledge of the consequences of digital and analogue material differences is an important artistic skill.

From tool management to material-entangled collaboration

Despite the fruitful analogy between the pencil and the computer as tools, the tool metaphor has its limitations. The rapid digital acceleration of artificial intelligence still offers new modes for generative art-making (e.g., Manovich & Arielli, 2023). The present distribution of the Generative Pre-trained Transformer (GPT) to a larger audience is the result of a technological development starting in the 1950s. Currently, it is the uncontrollable use of GPT that must be tackled given that this development is far-reaching. In artistic contexts, a theoretical transition away from the tool metaphor towards a deeper understanding of art-making as a collaboration between man and machine is proposed. Our proposed "meaning-making assemblage" of human and non-human agency (Fenwick et al., 2011) is revealed in a practice where, for example, sketching on paper serves as a side-coach for TinkerCad's digital director, which Knochel argued to be the digital director (2016b). The concept of assemblage dissolves the idea of the intentional singular artist in favour of collective collaboration and transcends the boundaries between materialities. Moreover, the entangled practices reinforce group work – sometimes cooperatively by distributing roles between students and students and students and non-human actors – sometimes collaboratively by entangling the ideation and design processes, as observed in the study of 3D digital modelling.

Collaborative skills in meaning-making assemblages of non-human and human agency are an important art-making skill.

CONCLUSION

Unfamiliar concepts such as coding, programming and computational thinking on one hand point to current societal challenges that the teaching subject of visual arts education cannot ignore as they form part of the contemporary art scene to which education relates. Contemporary art's conceptual approach to visual projects invites a new view on art-making. The socio-material perspective can help to shed new light on the interaction between human and non-human actors in the art-making process. Art-making practice understood as 'using a tool on a material towards an object' is replaced by art-making as a system of activity that initiates a process. The socio-material perspective (Fenwick et al., 2011; Fenwick & Landri, 2012) can counteract the development of dichotomies with, for example, classical sculpting as one pole and the digital concept as the other. The study should be seen as a first step in rethinking the didactics and pedagogical framing of art teacher education. The study's theoretical perspective offered a focus where subject paradigms, bodies, computers, pens, cardboard, paper and so on were all included as actors in the assemblage for meaning-making. This generated a subject-renewing theoretical perspective on art-making practices and indicated new ways of thinking about visual arts education that can expand or perhaps even innovate the theoretical and practical framework for visual arts education.

From this perspective, digital technology not only offers new digital activity forms; it exposes the traditional means of thinking about art-making processes. The perspective suggests a conceptualisation of art-making processes as an entangled collaboration and thereby an opportunity for integration with computational activities such as coding as the becoming of meaning-making.

REFERENCES:

Andersen, L. B., Brabrand, C., Buhl, M., Caprani, O., Georgsen, M., Hachmann, R., Hjorth, M., Jørnø, R., Køhrsen, L., Misfeldt, M., Toft Nørgaard, R., Nortvig, A-M., & Middelboe Rehder, M., (2022). *Anbefalinger til indførelse af teknologiforståelse i uddannelse af lærere og andet pædagogisk personale*, 56 s. Proceedings of the European Conference on e-Learning, ECEL Bind 2020-October https://doi.org/10.34190/EEL.20.047

Bourriaud, N. (2005). *Relationel Æstetik* [Relational Aesthetics] trans. Morten Salling, Det Kongelige Danske Kunstakademi.

Buhl, M. (2019). "Computational thinking utilizing visual arts, or maybe the other way around." In R. Ørngreen, M. Buhl, & B. Meyer (Eds.), *Proceedings of the 18th European conference on e-learning,* (pp. 102–108). Academic Conferences and Publishing International. https://doi.org/10.34190/EEL.19.138

Buhl, M. (2002). *Paradoxal billedpædagogik. Variationer i læreruddannelsens billedkunstfag* [Paradoxical visual arts education. Variations in visual arts teacher education]. Danish University Press.

Buhl, M., & Skov, K. (2021a). Challenges in educating student art teachers in technology comprehension. In C. Busch, R. Frieß, M. Steinicke, & T. Wendler (Eds.), *Proceedings of the 20th European Conference on e-Learning, ECEL 2021* (s. 66-72). Academic Conferences and Publishing International. Proceedings of the European Conference on e-Learning, ECEL https://doi.org/10.34190/EEL.21.119

Buhl, M., & Skov, K. (2020). TechArt learning practices for 1st to 3rd grade in Danish schools. I C. Busch, M. Steinicke, & T. Wendler (Red.), *Proceedings of the 19th European Conference on e- Learning, ECEL 2020* (1 udg., Bind 19, p. 73-79). Academic Conferences and Publishing International. Danish Ministry of Education. (1991) *Billedkunst 1991/4. Undervisningsvejledning for Folkeskolen* [Visual arts education 1991/4. Guidance for teaching visual arts in the Folke School].

Buhl, M., & Skov, K. (2021b). "Har I robotter til at male for jer?": Et fagdidaktisk perspektiv på teknologiforståelses fagfornyende potentiale i billedkunst [Do you have robots to paint for you?": A subject didactic perspective on the subject-renewing potential of technological understanding in visual arts]. *Learning Tech, 10*, 382-404. https://doi.org/10.7146/lt.v6i10.125610

Danish Ministry of Education and research (1991). Lov om uddannelse af lærere til folkeskolen. Bilag 2, Billedkunst [Act of teacher education for Folkeskolen. Appendix 2, visual arts education].

Duncum, P. (2010). Seven principles for visual culture education. *Art Education, 63*(1), 6-10. DOI:10.1080/00043125.2010.11519047

Fenwick, T., & Landri, P. (2012). Materialities, textures and pedagogies: socio-material assemblages in education. *Pedagogy, Culture & Society, 20*(1), 1-7. DOI:10.1080/14681366.2012.649421

Fenwick, T., Edwards, R., & Sawchuk, P. (2011). *Emerging approaches to educational research. Tracing the sociomaterial.* New York: Routledge.

Flensborg, I. (2002). *Aesthetic perspection in graphical user interfases.* Studies in visual arts education. The Danish University of Education.

Freedman, K. (2003). *Teaching visual culture: Curriculum, aesthetics, and the social life of art*. Teachers College Press.

Gude, O. (2004). Postmodern principles: In search of a 21st-century art education. *Art Education, 57*(1), 6-14.

Illeris, H., Buhl, M., & Flensborg, I. (2004). Visual Culture in Education. *Nordisk Pedagogik*, 4(24), særnummer.

Kiefer-Boyd, K. T. (1996). Interfacing Hypermedia and the Internet with Critical Inquiry in the Arts: PreserviceTraining. *Art Education, 49*(6), 33-41.

Knochel, A. D. (2016a). DIY Prosthetics: Digital Fabrication and Participatory Culture. *Art Education, 69*(5), 7-13. DOI:10.1080/00043125.2016.1201401

Knochel, A. D. (2016b). Photoshop teaches with(out) you: Actant agencies and non-human pedagogy. *Visual Arts Research, 42*(1), 71-87. DOI:10.5406/visuartsrese.42.1.0071

Knochel, A. D., & Patton, R. M. (2015). If Art Education Then Critical Digital Making: Computational Thinking and Creative Code. *Studies in Art Education, 57*(1), 21-38. DOI:10.1080/00393541.2015.11666280

Latour, B. (1999). *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA: Harvard University Press, p. 24-79.

Latour, B. (2005). *Reassembling the social: an introduction to actor-network theory*. Oxford University Press.

Luhmann, N. (1993). Die evolution des Kunstsystems. *Kunstforum*, (124), 221-278.

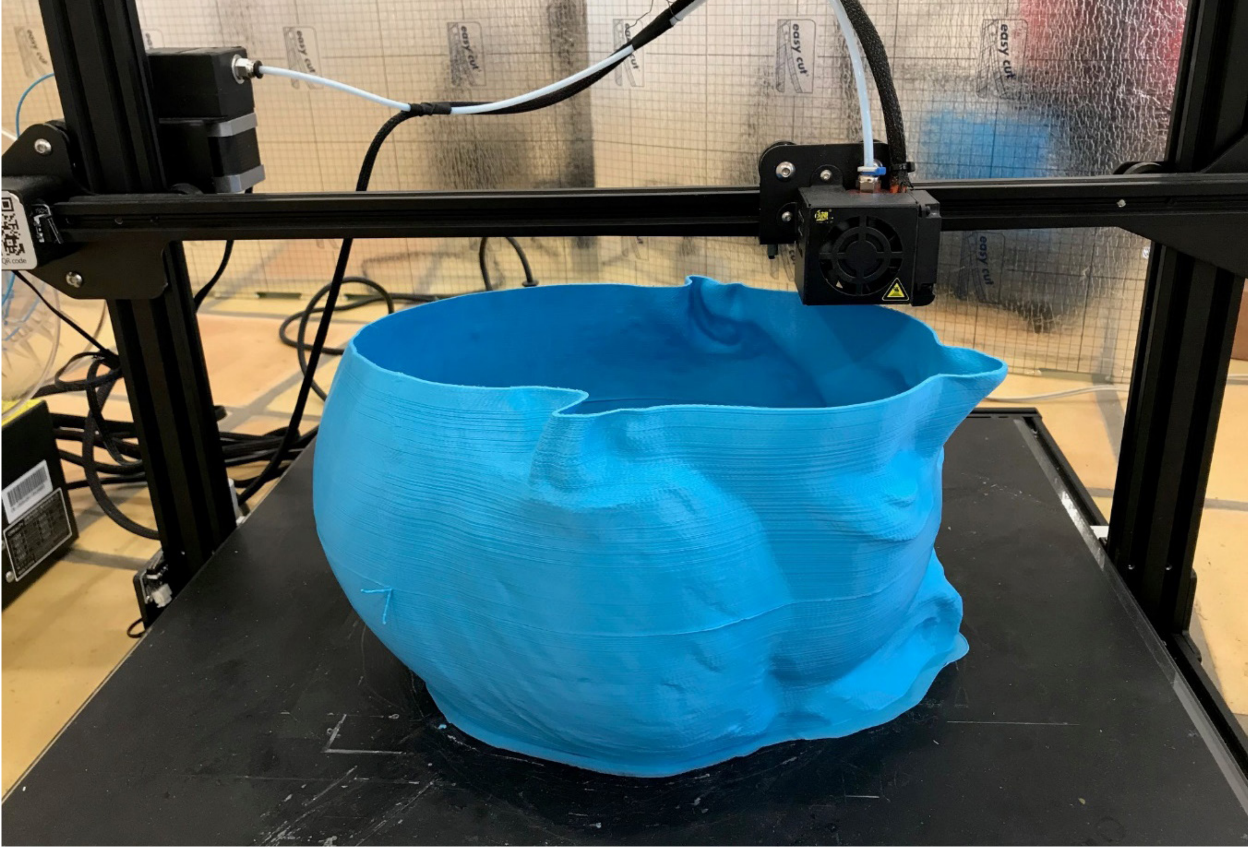
Manovich, L. & Arielli, E. (2023). Artificial Aesthetics: A Critical Guide to AI, Media and Design, Creative commons. manovich.net and gc-cuny.academia.edu/LevManovich

Pedersen, K. (2004). *Rekonstruktion af billedpædagogikken* [Reconstruction of art pedagogy]. Copenhagen: Danish University of Education Press.

Rasmussen, H. (2017). *Kompleks betydningsfremstilling i digitalt billedarbejde og billedæstetisk kompetenceudvikling i skolen - En Design-Based-Research-inspireret undersøgelse af, hvordan it- didaktisk design kan fremme læringsudbyttet af digitalt billedarbejde på iPad på 5. Klassetrin* [Complex meaning-making in digital visual production and visual aesthetic competence development. A design-based research study of how ICT–didactic design can promote digital visual production using iPads in fifth grade] [Doctoral dissertation, Aalborg University]. Aalborg University Press.

Skov, K. (1988). "Computeren som velkommen deltager i en proces [The computer as a welcome participant in a process]". *Billedpædagogisk Tidsskrift* 4.

Wing, J. M. (2006). "Computational thinking." *Communications of the ACM, 49*(3), 33-35. https://doi.org/10.1145/1118178.1118215



3D digital modelling in action, Kongegården 2021, Photo: Mie Buhl

'Wrestling' with 3D printers, searching for materiality – Morten Modin

Mie Buhl & Kirsten Skov

INTRODUCTION

3D printing might be considered boring for artists engaging with exploring contemporary conditions for life, society, and existence. Do digital technologies offer any possibility to go beyond the accurate, the predicted and the calculated? How is it possible to produce a 3D printed artefact of any consequence to a contemporary discourse dealing with the big questions?

Of course, this rather polemic entrance disregards recent Artificial Intelligence (AI) development where deep learning processes offers one visual piece after another inviting everybody to prompt their text-based request for a visual product. What is nagging is the smoothness of the solutions the latest apps for generating images via text prompts such as Midjourney and Dall-E can provide that adds to the boring connectedness derived from algorithms. However, recent AI based on neural networks of deep learning is still considered in its prime and the inter-

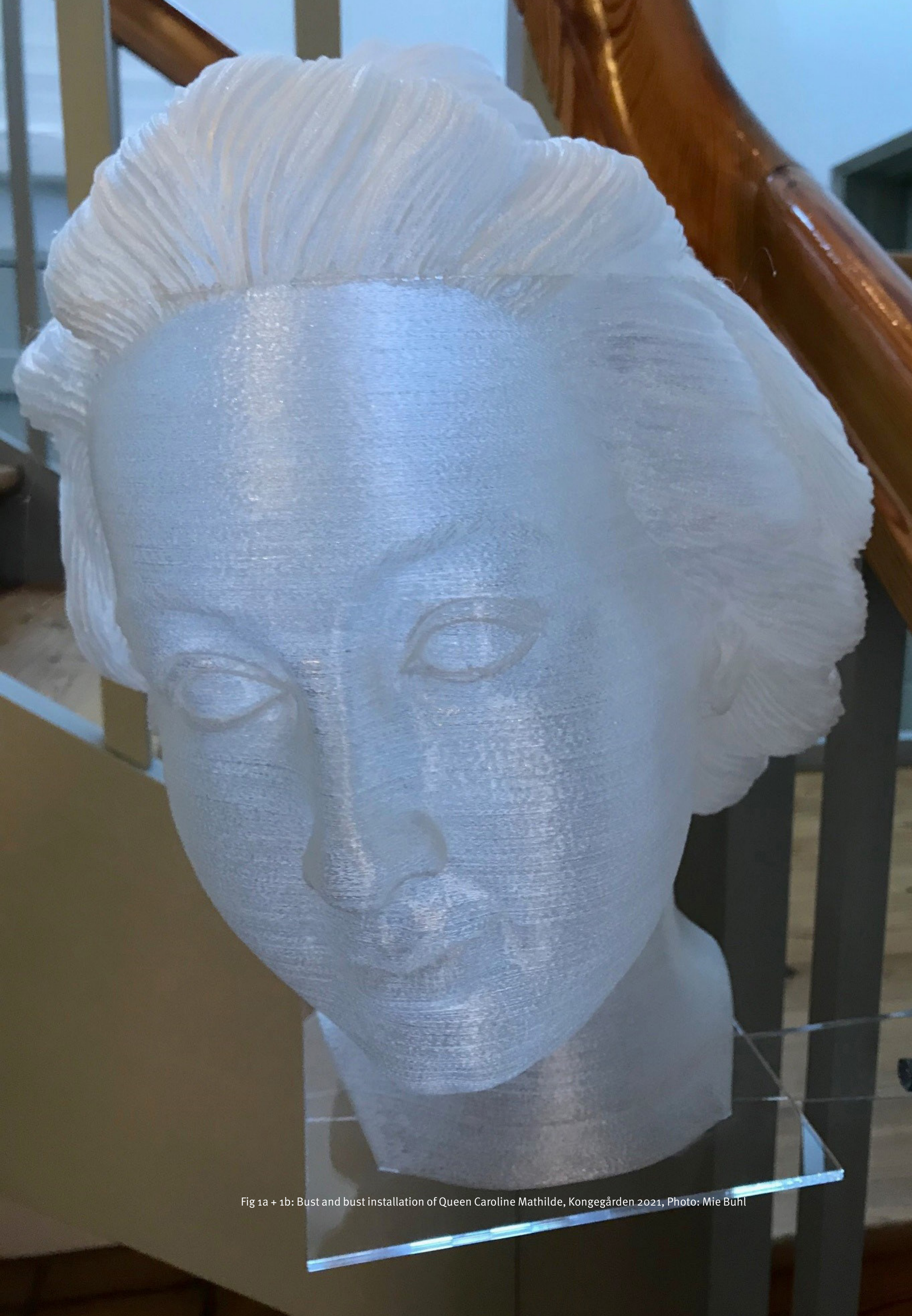


Fig 1a + 1b: Bust and bust installation of Queen Caroline Mathilde, Kongegården 2021, Photo: Mie Buhl esting work will emerge eventually in the hands of artists (e.g., Manovich 2023).

AI taken into consideration makes the question mark even bigger in an educational context: What are art educators supposed to teach future teachers if technology performs all the actions that displaces modelling material, experiencing the qualities of the hand? How can they learn from contemporary professionals in the field?

The scepticism about 3D digital modelling and print questioned in the hands of the Danish artist Morten Modin when he tests its limitations and expands possibilities and not least inquires the becoming of living a contemporary life entangled with digital technology.

This article is based on conversations with Modin during the Nordic project on 3D digital modelling in visual art teacher education, where a group of art educational researchers gathered to explore 3D digital modelling and was inspired by him. Furthermore, it is based on Modin's written material that he generously has shared with the authors. The following provides an insight into his exploring of aesthetic qualities as well as digital and analogue materialities in 3D digital modelling and print where he pursues 'the imperfect' in various settings.

MORTEN MODIN EXPLORING DIGITALITY, SPACE AND BEING

Modin is fascinated and concerned with how digital data affects our lives. The fact that we sometimes meet more in digital spaces than physical ones, how does this affect our understanding of materiality and volume? And how does it affect our bodily experiences when the physical aspect is not present in large parts of our social encounters? Using the 3D printer as his main tool, as well as several digital tricks such as manipulation of big data and 3D scans, he works to materialise the alienating impact he believes technology has on our lives. Modin works at the intersection between people, materials and data merge. He explores and exposes the transformations that take place between the analogue and the digital, and his 3D printed works (often) bear clear digital, processual traces. This can be in the form of something interrupted, something disturbed, something imperfect, missing or deprived of information, and therefore appearing in a hybrid or transcendent form between material, data, and human. It can be with clear traces of piecing and material composition. The site-specific location and context also always play a central role in his artistic production.

Example I: Redrawing our world as a digital shadow of what was

An example of a site-specific investigation of a historical phenomenon through 3D digital modelling was his exhibition *De uønskede (The Unwanted)* from 2022, Kongegården, Korsør Denmark. At this exhibition he incorporated site-specificity from a dramatic historic legacy about the love story between the Danish Queen Caroline Mathilde and King Christian VII's German personal physician Johan Friedrich Struensee. The love story had a tragic outcome involving exile and decapitation of the two lovers respectively, but an exert from their lives were transformed into works created from digital files.

According to historical records, the two stayed at the Kongegården for a year before their final fate of exclusion and death in 1772 (Broch-Lips, 2021). This inn was a natural stop for wealthy travellers waiting to cross the Danish waters between Zealand and Funen named the Great Belt. There are not many visual representations of the two people from the period probably due to public perception of their disgraceful actions. Modin changed that by creating *The Unwanted*. Based on paintings and sketches, he made 12 3D printed, colourful busts of Caroline Mathilde (1751-75) (fig 1a + 1b) and a large 3D printed bust of Friedrich Struensee (1737-72) (fig. 2a + 2b) in 2021

Fig 2a + 2b: Struensee in total and close-up of a deliberate ‘imperfection’, 2a: Photo: Buchwald 2b: Photo: Mie Buhl

Fig. 3: Examples from site-specific clusters of items. Kongegården 2021, Photo: Mie Buhl

Fig. 5a + 5b: Installation. Bærum 2021, Photo: Ulstei

as a testimony of their stay in the royal suite at Kongegården.

Modin explored transformations that occur between analogue and digital modes and how these change our experience of an object. He describes his fascination with projecting 3-dimensional objects into an image (2-dimensional) and then projecting it 'out' again. These leaps in space can question and challenge our perception of what and where reality is. He constantly marvels at what happens when he 3D scans an object, digitally processes it on the computer and 3D prints or CNC mills it 'out' into reality again.

It is like an outline of something that was, a perfection stripped of information, an indication of an object, place or event frozen in time. His process of working with works that go from being in a physical universe to existing in a digital space and then reappearing from a physical material, gives the experience of the finished work as a collapse in our perception of space and existence. When he 3D prints J. Friedrich Struensee in 2 m x 2.5 m x 2.5 m and Queen Caroline Mathilde in a 1:1 bust format, it is to emphasise how the digital world can accurately 'redraw' our world, but at the same time is only a digital shadow of what was, a processed snapshot.

Modin connects the human body and digital processes into new physical works. He sees the transformations that happen between analogue and digital states as a change in our experience and concept of objects and the reality it belongs to. Modin refers to his works as 3-dimensional *shadows* as they are not something complete in themselves. By placing his work in specific physical contexts, the foundation of digital identity changes from being ubiquitous to become unique and relevant for the present surroundings. His workflow is process-orientated, but the 3D printer's automation challenges the sculptures' process-oriented

constructability. An example of that was the work 'Struensee' where the 3D printed parts were assembled in the exhibition space itself. A physical limit was then placed on the "unfolding" of the digital files.

Example II: site-specific unorganized network of accumulations of 3D prints, everyday artefacts and busts

Other 'inhabitants' in Kongegården is the collection of works performed by the artist Harald Isenstein (1900s), who had a local affiliation with Kongegården. Today, Kongegården serves as the local exhibition hall in Korsør. While the works of Caroline Mathilde and Struensee were placed on levels 1 and 2 of the building, level 0 was used by Modin to create an artistic installation of objects that included Modin's selected busts of Isenstein, found everyday objects of aesthetic value and his own 3D printed objects (fig 3).

All the objects were placed in organic collections that utilised the rustic space for a site-specific installation that created remarkable clusters and surprising juxtapositions (fig.3). He described it as accumulations that

> *consist of found materials, sketches, discarded and finished works all in an unorganised network. It's like stepping into a primordial soup where you become an object like any other material. The eye and mind's focus on the overall work disappears in favour of the individual objects and their uniqueness. (Broch-Lips, 2021).*

Example III The process of 3D as a transcendence from a physical universe, to exist in digital space and re-emerge from a physical material.

For the exhibition *Superpositions,* Bærum Art Hall in Norway (2021), Modin wanted to create an intimate and personal exhibition. He aimed to explore the borderland between man and machine, by making a critical posthumous portrait merger identity, data, and material in new and previous works.

The actuality of the exhibition was evident as it scrutinised our perception of identity and reality in a digital age where algorithms, 'big data' and artificial intelligence are incorporated and control more and more levels of our lives. Modin aimed at challenging our concept of – or sense of – what is true and false drawing on the classic Cartesian question of how we actually exist and in what physical/material form suggesting that perhaps we can only know that we are thinking subjects?

The exhibition comprised physical 3D printed sculptures that Modin based on 3D scans of his own body in different compositions and contexts (fig 5a + 5b). The expression of the sculptures was at once realistic and at the same time sensed the digital errors and manipulations that occur and are created in the digital state (processing). A state that can be described as a three-dimensional shadow work, an imperfection, an indication of an object or event frozen in time and place. Furthermore, the works represented a sculptural practice where the sculptor's craftsmanship is more about understanding digital 3D work, including processing the materiality of the work in a digital format, rather than the classic physical material properties. However, the 3D printed works were 95% plaster, following the tradition of the sculptor working with plaster, but in a mechanical and conceptual way. Modin explained how the title 'Superposition' refers to the quantum mechanical phenomenon where a physical system can theoretically exist in multiple possible states simultaneously but can only be observed in one of the states at a time. It refers to his reflections on a possible future where the difference between the digital world and analogue physical world has dissolved into one and the same world. This aspect is also present in the working processes of the 3D printed works, as they go from being in a physical universe to existing in digital space and then re-emerging from a physical material. The finished work then becomes a kind of collapse in our perception of space and existence. Thus, the exhibition 'Superposition' became a critical look at our contemporary world where body and mind merged with polygons and data. Here, Modin touched upon a questioning of the anthropocentric worldview confronting us with human and non-human agency entangling and thereby provides a de-centering of human intentionality as driver of changes.

RESETTING OF ARTMAKING PRACTICES AND LEARN FROM IT IN VISUAL ARTS EDUCATION

With his critical and curious approach to digital tools, Modin discovers new possibilities for exploring digital and analogue materials by transcending traditional ideas of materiality. His purpose is to re-evaluate our understanding and view of how digital image spaces are viewed and represented. He wants to strip the 3D printer of its attributes as a mass-producing and autonomous machine but retaining the digital space of possibility. Contemporary discussions of digital technologies centre on AI and robotics. As AI is increasingly utilised and used to solve societal problems, it is also increasingly becoming a controlling factor in our lives. Modin believes that even though the development is still in its infancy and could, in principle, take all sorts of twists and turns, the visual arts also have a responsibility to contribute to the discussion of how AI is used and can influence artistic expression. In the sculptural field, Modin sees a huge potential to get help from robots and machines. He asks the pertinent question that if AI is increasingly playing a role in processes that were previously driven by craftsmanship, how do contemporary artists, for example, still manage to be artistic directors and manage this tangle of digital helpers?

From an educational perspective we must ask, how visual arts education become an active partner in the new digital landscape where art making also concerns the skills of managing all the digital helpers provided by AI?

First and foremost, we can learn from Modin's fearless approach to digital technologies. Using the 3D printer as his "collaborator", he inspires a didactic transformation in education. He feeds the image-making practice with data and various inputs. He transforms digital bits into atoms, and the final expression is a physical three-dimensional object with digital traces in the form of errors, flaws, and failures. The imperfection that may be perceived as errors for the engineer, and be the reason for waste and destruction, is for Modin the key to making 3D printed objects appear human and unique:

> *When the 3D printer gets stressed and the software is exceeded, it fails as an autonomous machine and suddenly becomes a manageable artistic tool that I have control over (Modin, 2021)*

So, the key to learning from Modin's 3D modelling may be his approach as a collaborator with digital technologies rather than a tool manager. A collaborator who makes conceptual choices in the processing of different digital and analogue materialities and challenges AI's suggestions to produce perfection. Furthermore, it can inspire teaching to delve into the question of living in an AI-entangled age and use art's ability to question the obvious, self-evident, and smooth. A 'wrestling' with modelling, printers, materialities – and life.

REFERENCES:

Broch-Lips, H. (2021). *Morten Modin. De uønskede*. Kongegården

Manovich, L. (2023). *Artificial Aesthetics: A Critical Guide to AI in Art, Media and Design,* http://manovich.net/index.php/projects/artificial-aesthetics-book

Source:

Modin, M. (2019-2022). *Selected text material belonging to the author*

Digital 3D modelling as an expansion of the aesthetic repertoire for image-making practices. Concluding discussion

Mie Buhl & Tarja Karlsson Häikiö

The Digital 3D Modelling in Visual Arts Education project was initiated to investigate how the use of digital technology can contribute to creating new perspectives on the classical sculpture techniques that are characterised by 'adding', 'carving' or 'modelling' analogue materials. Furthermore, the project aimed to explore the image-making practices that exist in the interlocutory space between analogue and digital materialities. By identifying new image-making processes in one of the most important areas of visual production: sculpture, the project wanted to contribute to the development of new image-making practices as well as to a framework for discussing visual arts education considering recent developments in artificial intelligence (AI).

The theoretical framework of the project drew on insights from studies in computational thinking in visual arts education (e.g., Knochel & Pattern, 2015) and visual culture studies (e.g. Knochel, 2016) and the research was inspired by design-based research (DBR) (Amiel & Reeves, 2008). As a part of exploring and understanding digital 3D modelling, the project participants engaged in practicing sculpting in analogue materials and digital 3D modelling by using TinkerCad and photogrammetry. The digital applications were used as drivers for the hand-on activities and reflections in the explorative phase of the project. This process, followed by a process of designing for student art teachers learning, facilitated a transformation of own image-making experience into didactic consideration and generating new theoretical insights (Buhl, 2016). Thus, the group's hands-on experiences and mutual reflective insights fed into their image-making competence within sculpting as well as their subject didactic planning and teaching at their home institutions. The learning design and teaching practise served as empirical data for the subprojects presented in this special issue (chapter 1, 2, 3) and the findings were further elaborated on in a discussion with artist Morten Modin (chapter 4). Based on the overall research questions (see the introductory chapter), perspectives on the three sub-projects' contributions are presented in the following.

THE SUBJECT MATTER VISUAL ARTS BALANCING BETWEEN THE EXPRESSIVE AIMS IN ART MAKING PRACTICES AND THE SKILLS REQUIRED FOR USING PROGRAMMING

The three projects explored the balance between expressive aims in art practices and programming by taking different starting points. Hildén and Karlsson Häikiö's (chapter 2) learning design started with manual modelling of a material followed by a digital process with photogrammetry and TinkerCad ending with a digital 3D print, while Heinonen and Marklund's (chapter 1) learning design made the manual modelling a continuous process after starting with the digital 3D modelling in TinkerCad and

3D printing. As for Buhl and Skov (chapter 3), the starting point in their learning design was the physical encounter and sketching activities of a site-specific urban place, followed by digital 3D modelling of an artefact for a digital intervention of this place, which was done in TinkerCad and virtually installed using an image processing program (GIMP). The processing of digital material in the three projects did not dictate a certain linearity or order of production; rather, it showed flexibility not only within the digital modelling process, but also in regards of how it could take a meaningful place in the interaction with analogue materials throughout the image-making process. The linear process of creation governed by material qualities – digital as well as analogue – thus took new directions in terms of when and how the actual creation of the sculptural form took place. It took new directions in terms of what materiality was at play in the aesthetic design process, as one of the projects worked with a transformation of analogue material for digital processing and later a printed materialisation of the digital form (chapter 2), while the digital aesthetic design process was prior to physical manifestation in another (chapter 1), and the physical manifestation of the sculptural artefact was absent in the third (chapter 3). The question is, of course, to what extent the sequence of processing and realisation of a physical manifestation affects the aesthetic learning process, and this cannot be concluded from the present findings. On the one hand, the actual execution of programming activities took up a lot of time because it was an unfamiliar practice for the students, and on the other hand, other aspects played a role, such as the fact that the subprojects were not designed as comparative studies beforehand. It was not the goal of the project to identify learning outcomes, but rather to examine how the repertoire of aesthetic expression expands and/or changes using programming for 3D modelling. Here, the sub-projects showed the temporal flexibility of working with digital material for sculpting, along with the exploitation of aesthetic qualities by testing scaling and contextualising an artefact in changing location.

ENGAGING WITH THE PROGRAMMING AND 3D PRINT "TO BREAK NEW GROUNDS"

From this perspective of programming for image-making, the process of sculpting can be seen as a transformation of subject-related competences, since manual aesthetic modelling skills are not only replaced with aesthetic coding skills, and thereby a lack of bodily contact with material as suggested by Sack (2019). Rather the subprojects revealed expanded possibilities for new combinations of analogue and digital 3D modelling. The sculptures produced by digital interventions is not a replacement of a known sculptural process, but a new image-making process where the entanglement of digital, analogue material, physical surroundings constitute the image. Building on Morten Modin's work and insights (chapter 4), this ongoing 'wrestling' with materiality became a collaboration between man and machine, which have different qualities to offer the image-making process. As Hildén and Karlsson Häikiö (chapter 2) discuss in their article, the transition from analogue image-making to digital image-making increased a focus on haptic experience – a bodily knowledge of tactility – became a co-actor in understanding the volume, surface, and substance of the digital 3D object. This haptic experience directed the choices made in the process of transforming the analogue object in the 3D modelling in TinkerCad. Heinonen and Marklund's (chapter 1) study of how students approached the digital 3D modelling primarily revealed an intellectual problem-solving approach to translate an analogue artefact to a digital object. Drawing on Schön (2003), they interpreted the image-making process as a reflection-on-action rather than a process of tacit driven experiments which aligns the principles of concept art (e.g., Buhl, 2019). Their findings indicated that the programming process inclined an analytical processing at the expense of a more open experimental process among the participating student teachers. This may be because programming practices favour analytical actions, or because the student teachers' limited skills in programming for imaging put the focus on coding. Buhl and Skov's (chapter 3) study of 3D modelling practices showed that different parallel actions were enacted during their image-making process and performed as an entanglement of digital and analogue materials. This suggests that the interaction between ideation and visual drafts on both screen and paper can have a supportive effect in experimental processes and concept development in art making practices.

Nevertheless, for all three sub-projects, much of the attention in the aesthetic design process was spent on mastering programming and understanding the logic behind it. Practical image-making involving digital programming requires skills and knowledge of the principles behind. In recent years, schools and Teacher Education programmes in Sweden and Denmark have been working to develop digital literacy as a sole subject and discipline in existing subjects. The rationale behind the revitalising of elements from computer science such as computational thinking and programming and apply them to general education in schools, is the need for the future population to navigate in a society increasingly digitalising still more aspects of everyday life. The educational efforts are driven by the aim of students to be able to understand the logic behind computer-generated content, how it works for solving problems. The educational efforts are further to illuminate how digitalisation affects us as citizens and this challenge is not met by just being consumers. The obvious disciplines for dealing with the digital challenges are the disciplines from which the science emerge and develops namely data/computer science and math.

However, based on the digital entanglement in every aspect of civil life, the perspective must be broadened. Visual arts have a history of being first mover when engaging with new technology including digital technology (e.g., Manovich, 2023). Furthermore, the very 'DNA' of artistic work is to provide curious and critical questions to societal developments including the impact of digitalisation. In an educational context, visual arts hold the potential for providing approaches to acquire computational skills because of similarities between the logics of conceptual arts (visual production 'by rules') and logics of programming (data-production 'by rules'). Digital-based art production offers a new repertoire for contemporary meaning-making in visual arts education. To realise that new repertoire, we suggest that data is approached as a new material and are aligned with other materials such as clay and plaster. Furthermore, the practice of using computer science principles to produce visual expressions, actions and narratives must be accessed on the terms of aesthetic processes: explorative and experimental.

EDUCATIONAL IMPLICATIONS FROM USING PROGRAMMING IN MATTERS OF AESTHETIC QUALITIES, DIDACTICS, TEACHING COMPETENCES AND CHALLENGES OF 'SUBJECT MATTER-DNA'

The use of programming for 3D modelling practices in visual arts education raises some concerns regarding learning and new thinking patterns. The role of digital 3D modelling in the school subject is double: it is the tool for artistic expression when students experiment with devices and applications, and it is the topic for artistic expression when students inquire and explore the societal implications of man-machine in a world of social media, algorithms, and mobile technology. Technology educators Mayes and De Freitas (2013) discuss three interconnected learning paradigms that sum up how technological education is approached: 1) the associative learning paradigm referring to programmatic learning and training programs, 2) the cognitive learning paradigm referring to individual and constructive learning activities and 3) the situated learning paradigm referring to social and practice activities. The paradigms are recognisable in a visual arts educational discourse of a skill training-oriented focus (cf. 1), a personal development focus (cf. 2) or a social practice focus (cf. 3). The authors emphasise the interconnectedness between the paradigms and regarding digital 3D modelling the challenge is to balance the three paradigms rather than be overwhelmed by the skill-training focus.

The process of digital 3D modelling 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). However, the sculpture produced by digital intervention is not a replacement of a known sculptural process, rather a new image-making process drawing on the digital as one among more materialities for meaning-making (Fenwick & Landri, 2012). Digital 3D modelling 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 which may add new dimensions to discourse of artistic inquiry and aesthetic experiments. From a visual arts educational perspective, this may reinforce students' programming skills, or it allows students who are more skilled in programming than manual sculpting to express themselves visually.

The digital 3D modelling project group touched upon one – and well established – part of visual arts education and threw themselves into exploring it. The findings were limited to the conditions and circumstances under which they were performed. Still, we hope that peers will feel inspired to explore more aspects of AI driven technologies in the field of visual arts education.

REFERENCES:

Amiel, T., & Reeves, T. C. (2008). Design based research and educational technology: Rethinking technology and the research agenda. *Educational Technology & Society, 11*(4), 29–40.

Buhl, M. (2019). "Computational thinking utilizing visual arts, or maybe the other way around." In Ørngreen, R., Buhl, M., & Meyer, B. (Eds.), *Proceedings of the 18th European conference on e-learning,* (pp. 102-108). Academic Conferences and Publishing International.

Buhl, M. (2016). Theory-generating practice. Proposing a principle for learning design. *Læring og Medier*, *9*(15), 1-21. http://ojs.statsbiblioteket.dk/index.php/lom/article/view/23464/20871

Fenwick, T. & Landri, P. (2012). Materialities, textures and pedagogies: socio-material assemblages in education. *Pedagogy, Culture & Society, 20*(1), 1-7, DOI:10.1080/14681366.2012.649421

Knochel, A. D. (2016). Photoshop teaches with(out) you: Actant agencies and non-human pedagogy. *Visual Arts Research,* 42(1), 71-87. DOI:10.5406/visuartsrese.42.1.0071

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), 31-38.

Mayes, T., & de Freitas, S. (2013). Technology-enhanced learning. The role of theory. In Beetham, H., & Sharpe, R. (Eds.), *Rethinking pedagogy for a digital age: Designing for 21st century learning* (2nd edn, pp. 13–25). New York: Routledge.

Manovich, L., & Arielli, E. (2023) *Artificial Aesthetics: A Critical Guide to AI, Media and Design*, Creative commons.

Sack, W. (2019). *The software arts.* Cambridge, Massachusetts: MIT Press.

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