Unveiling the Potential of Digital Fabrication in Arts & Crafts Education: A Future Workshop Approach for Technology-Enhanced Teaching

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***Abstract*—This research paper explores the potential of Digital Fabrication (DF) to incorporate digital competences in arts and crafts (A&C) education. With the growing emphasis on digital literacy in K-12 curricula, we aim to investigate what opportunities and challenges DF can bring to A&C education. To achieve this, we conducted a Future Workshop with seven A&C teachers from two different primary schools. Through the Future Workshop approach, we were able to engage teachers in a participatory design process that enabled them to explore the potential of DF in A&C education. Teachers shared their perspectives, identified challenges, and brainstormed future solutions. The findings reveal that teachers see clear opportunities of DF to introduce topics related to STEAM (Science, Technology, Engineering, the Arts and Mathematics Education), sustainability and product design in A&C education, but there are also challenges that need to be addressed, such as lack of equipment, knowledge, or time constraints.**

Keywords- future workshop, teacher training, digital fabrication, arts and crafts education

I. INTRODUCTION

The translation of digital designs into physical objects is known as Digital Fabrication (DF), involving tools like 3D printers, embroidery machines, laser cutters, and vinyl cutters. DF technologies have become affordable and accessible at Makerspaces and FabLabs around the world. They enable individuals to create professional-looking items quickly and at a relatively low cost. According to Blickstein [1], DF and making can have a significant impact on education by introducing powerful ideas, literacies, and expressive tools to children. There have been recent efforts to incorporate programming and digital technologies into A&C curricula [2], with teachers utilizing DF to teach programming, making, and design thinking to students [3]. The potential applications of DF in A&C education are numerous, including accessibility, versatility, collaboration, customization, automation, and innovation. DF provides a distinct approach to model-making, allowing students to experiment with new materials and techniques while facilitating alternative forms of collaboration among students. Song et al. [4] found that DF activities can inspire teachers to explore alternative approaches to A&C, utilizing technology to push the boundaries of traditional crafting techniques. Previous research has explored DF in A&C mainly as part of STEAM projects and with the aim to introduce computing to diverse student groups using robotics, e-textiles and 3D as most common DF themes [5]. However, in K-12 A&C education, the uptake of DF technologies is lagging. A national education report from 2009, which analysis the use of digital tools in Norwegian schools, [6] found that A&C teachers incorporate low levels of technology in their K-12 practice. This corresponds with relevant research on challenges incorporating technology into arts education [4], [7]. In this paper, we are interested in how A&C teachers reflect on DF and its potential in K-12 A&C education, as a first step in creating a local professional development project. In Section 2, we review technology use in A&C education, before discussing the future workshop approach in Section 3. We present our method in Section 4 and our findings in Section 5. We conclude the paper with future work in Section 6.

II. TECHNOLOGY IN ARTS AND CRAFTS EDUCATION

While digital tools have been introduced in education in general, there has been minimal use of technology in arts education compared to other subjects. Song et al. [4] found the reluctance of arts education to embrace technological advancements is not a new phenomenon. Art is considered a media-specific subject, and the interaction between material and process is integral to student learning [8], [9]. Technologies used in this domain have been limited to ICT, image and video editing, and graphic design, which are predominantly virtual and two-dimensional e.g., [10]–[12]. Ettinger [8] has documented the use of digital tools in arts education for information gathering, particularly using the internet. In 2019, policymakers in Norway emphasized the importance of digital literacy by introducing explicit changes in all subjects, including A&C education. The changes in the K-12 curricula include a clear description of digital literacy as core elements. For A&C education in grades 5-7, the changes included:

- Using digital tools to plan and present processes and products (Core element: Art and Design Processes)
- Implementing programming to create interactive and visual expressions (Core element: Visual Communication)
- Learning how to safely and sustainably use electrical crafting devices with specific materials (Core element: Handcrafting)

TABLE I
EMERGING THEMES IN THE CRITIQUE PHASE

Economy	Lacking equipment Difficult to finance purchase Cost of raw materials Lacking dedicated rooms for DF
Knowledge	No experience with DF No experience with the equipment How to evaluate pupils' work How to make good tasks Need new work routines
Structure	Big classes, need extra teachers Need to learn together, in a community Need cross-disciplinary cooperation, can't teach all basic skills in A&C
Time	Need time to learn new skills Time is limited

For A&C education in grades 7-10, the changes included:

- Exploring the use of technology with materials when constructing products (Core element: Handcrafting)
- Exploring how new technologies can enhance creative processes when creating products (Core element: Art and Design Processes)
- Learning how to create interactive illustrations using hand drawing, 3D modeling, and other digital tools (Core element: Visual Communication)

III. FUTURE WORKSHOP IN TEACHER TRAINING

A future workshop is a participatory and collaborative approach to generate ideas and solutions for a desirable future through critique, fantasy, and implementation phases [13]. The origins of future workshops (FW) can be traced back to the 1950s, when Austrian futurist Robert Jungk organized meetings for a citizen group to address common problems. The aim was to create ideas for a desirable future and critique the establishment through collective decision making and group synergy effects. Three main sources inspired Jungk's approach, as described in [14]: the socialist principles of participative, democratic, and critical citizen decision making for the initial critique phase, Alex Osborne's brainstorming method for the following fantasy phase, and methods based on group synergy effects and individual intuition for the concluding implementation phase. FW has been utilized in teacher training. Forsler [15] introduces teacher students to FW to visualize media infrastructures in teaching spaces. Dirckinck et al. [16] use FW to involve teachers in the design and implementation of digital learning platforms. The bottom-up approach of FW aligns with our research aim, which is to learn about teachers' concerns integrating DF in A&C education; as well as teachers alternative visions of an ideal future using DF in A&C education; ending up with a set of concrete action for us to support teachers in the process.

IV. METHOD

In the following, we will describe how we have implemented the FW and collected and analysed data from the workshop. The workshop took place on a Thursday from 4:00-6:00 pm in a meeting room at the university, with two DF experts (authors of this paper) and seven teachers from two local secondary schools (four women and three men). An email invitation was sent to A&C teachers from local schools. We invited all interested teachers. They had minimal or no experience with DF. One DF expert facilitated the workshop, while the other gave a short presentation on DF and supported the facilitator during the activities. The workshop began with some food and coffee to help participants get to know each other and warm up for the workshop. The workshop was structured as follows:

- Introduction to DF: 10-15 minutes
- Problem phase: 30 minutes
- Critique phase: 30 minutes
- Implementation phase: 30 minutes
- Summary and planning for the upcoming workshop.

In the *critique phase*, we prompted participants to brainstorm and identify hindrances or problems that could prevent them from using DF in their teaching. Each participant was asked to write down at least three issues individually, while they could talk to each other for about 10 minutes. Next, we sorted and grouped the raised concerns to identify common themes among participants. Finally, we concluded the critique phase with a brief discussion where participants elaborated further on the emerging themes.

In the *fantasy phase*, participants engaged in activities similar to those in the critique phase, where they individually wrote down ideas before we grouped and discussed them. Instead of identifying problems, participants imagined an ideal, utopian situation where they could envision the full potential of DF without any limitations. This included imagining that all identified problems from the previous phase were solved and there were no restrictions. The aim was to gain insight into how teachers envision using DF in their teaching.

During the *implementation phase*, the ideas and limitations, that were identified in the earlier stages, were evaluated against each other to determine their feasibility in the current situation [14]. The teachers reviewed the previous themes and prioritized them, discussing the necessary requirements for implementing each idea, leading to a prioritized action plan for future workshops in the project.

To collect data, we videotaped the workshop and conducted a thematic analysis of the data for each phase. We then engaged in a discussion where we compared and consolidated our coding to identify common themes. Thematic maps [17] were created for each phase, and any discrepancies in the coding were addressed and resolved through further discussion.

V. FINDINGS

During the critique phase, teachers have identified several challenges to using DF in their teaching, which we have

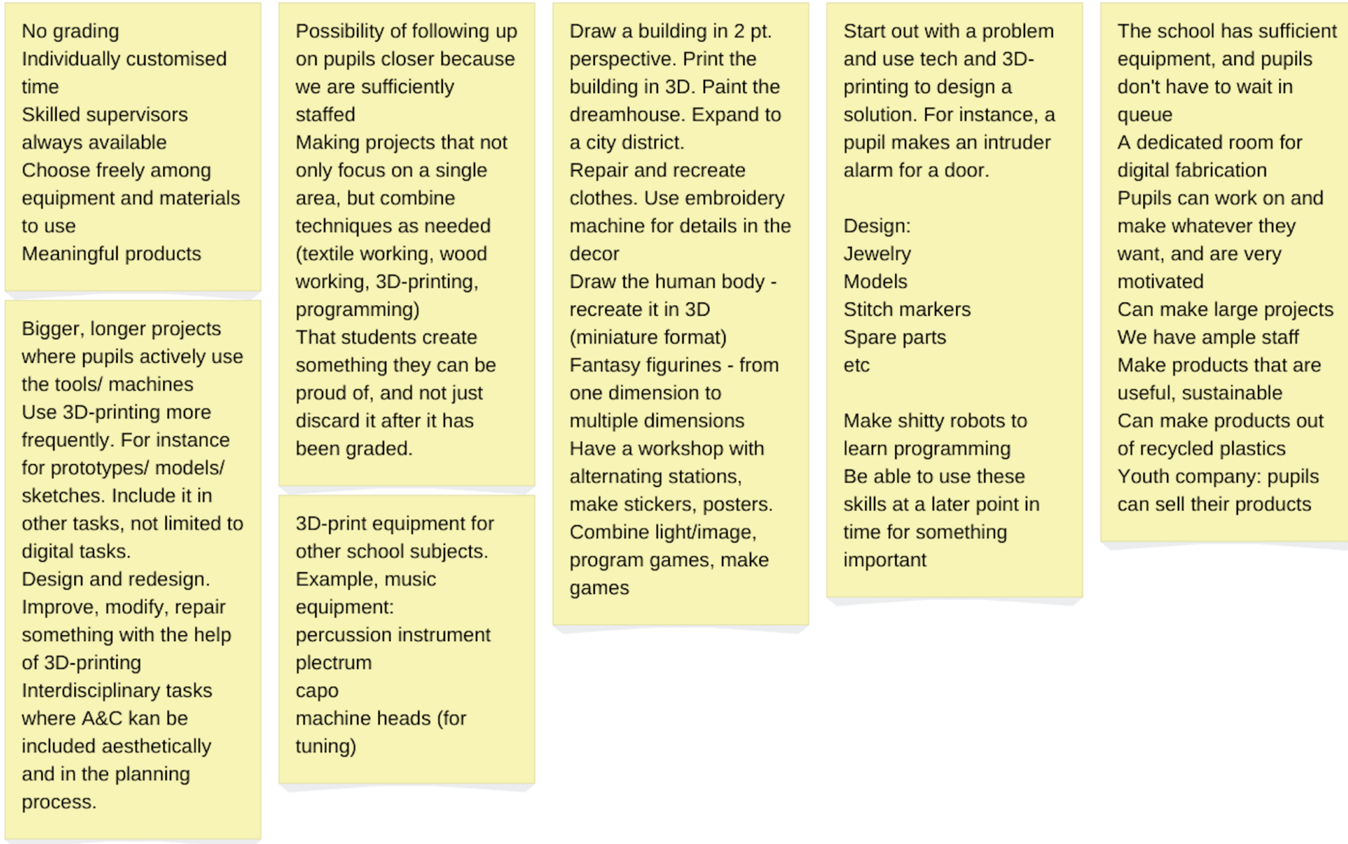

Figure 1. Postit notes from the fantasy phase, translated

grouped into four categories as outlined in Table I. *Economic challenges* are one of the main concerns, such as the lack of access to DF equipment, the cost of materials, and the absence of dedicated spaces for DF activities, such as a makerspace. Teachers find it difficult to ask for money to buy DF tools due to budget constraints and purchase restrictions in schools. However, in one school, the *lack of knowledge* is the most immediate challenge using DF, despite having three 3D printers. The person responsible for buying the printers has left, resulting in the printers being neglected, since no one in the school knows how to use, maintain, or repair them. In addition, teachers also feel that they lack pedagogical knowledge, such as how to create engaging DF tasks and assess student work. Due to *time constraints* and large class sizes, they feel unable to learn new skills on their own. They mention a need to establish a more *structured* way of support such as a community of practice in DF. They also recognize that DF should be incorporated into various subjects to spread the responsibility of teaching DF skills.

We categorized several opportunities for incorporating DF in A&C education, ideated by the teachers during the fantasy phase. One such opportunity is the potential for interdisciplinary projects that utilize a variety of technologies and techniques to create meaningful products. This aligns with the concept of STEAM, as well as the principles of design thinking and making, as discussed in existing literature [1], [18]. The teachers believe that the inclusion of DF in A&C will motivate students to create products they are proud of and that are meaningful to them. Additionally, they see opportunities for DF to be used in redesign, repair, and recycling projects as more sustainable practices. An overview of all generated ideas is depicted in Figure 1. Surprisingly, none of the teachers related their DF fantasies to the core elements of the A&C curricula.

In the implementation phase, the teachers identified two activities that address their lack of knowledge. Firstly, they requested 3D printing training to equip themselves with a better understanding of the technology, which they felt would help them evaluate how to incorporate it into their teaching. Secondly, they expressed a need for more inspiration and teaching examples, which they dubbed an ”idea bank”. The teachers considered these activities feasible to implement since they did not require input from other stakeholders.

VI. Future Work

In conclusion, the Future Workshop proved to be an effective method for exploring teachers' perspectives on DF for A&C education. Teachers gave positive feedback regarding both receiving information about possibilities in DF and the opportunity to express and share their thoughts on introducing technology in A&C education. The insights gained from the workshop will guide further interventions. To address the challenges raised by the teachers in the critique phase, we have identified several key steps that need to be taken. Firstly, we should establish DF technology workshops to provide teachers with the necessary knowledge and skills to incorporate DF into their teaching. Secondly, we could create a platform for DF ideas and resources based on existing sources such as Thingiverse and Printables. Additionally, we aim to build a community of practice in DF to foster collaboration and support among teachers and DF experts. Finally, we need to communicate with school owners to secure financial and structural resources for our undertaking. By taking these steps, we hope to effectively address the challenges highlighted by the teachers and successfully integrate DF into A&C education. The emergent themes in the fantasy phase inspire our work to develop interdisciplinary STEAM projects that incorporate diverse DF technologies.

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