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Empowering educators by developing professional practice in digital fabrication and design thinking

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ABSTRACT

The world is becoming increasingly automated, and the ability to deal with technologies is seen as important in society and working life. Digital fabrication (DF) and design thinking (DT) have been suggested as approaches to developing students' understanding of technology and their agency in a digitised world. However, nowadays teachers are not being trained in this field. In order to prepare the next generation for a rapidly changing and unknown future heavily influenced by computing it thus seems necessary to focus on the professional development (PD) of teachers. This study investigates how development of professional practice can be conducted to empower teachers and principals to implement DF and DT activities in schools. Initially, the paper gives an overview of nine educational initiatives in the field, followed by a closer examination of the Danish FabLab@SCHOOLdk organisation. The paper identifies the different PD programmes aimed at empowering in-service teachers, pedagogues, and principals in the field of DF and DT. As the main contribution to the research community, the study identifies five important stakeholders that are supporting and operating in synergy inside the FabLab@SCHOOLdk initiative as well as the surrounding gatekeepers with influence on the development processes. The paper further illustrates how the stakeholders operate in the organisation to enable educators to apply DF and DT in schools and discusses the development of professional practice in this field. Finally, a 1:1:1 -model for realising research-based suggestions in PD programmes is presented.

1. Introduction

The ability to deal with technologies is seen as increasingly important in society and working life. The current generation of young people seems to excel in using general technological tools such as computers and smartphones, and they are quite familiar with information and communication tools, making movies, editing photos, and creating web pages. It is alarming though that less than half of them can create something by means of exploration and fabrication technologies, such as 3D printers, vinyl cutters or fixing electronic devices [1]. How can we turn these passive consumers into critical, creative, and competent thinkers and producers — for the sake of individual '*Bildung*' and for the sake of the society?

The benefits of applying *digital fabrication in education* has been discussed by many researchers [2–5]. *Digital fabrication* (DF) has been described as the next generation's 'information technology' [6]. In this study, DF refers to a variety of new digital technologies such as laser cutters, CNC milling machines, and programmable electronics, applied in explorative, creative, and reflective problem solving, and to digital manufacturing processes for designing and producing prototypes and products. DF can enhance students' existing practices and expertise, accelerate the processes of invention and iterative design cycles, allow students to engage in intellectual, long-term activities and practices, and experience new levels of collaborative work [2]. By engaging learners to combine the physical activity and abstract thinking [5] or digital tools, such as in designing electronic textiles, educators can reveal how digital media is made and designed and enhance students' abilities within problem solving and designing with technologies [4].

Lassiter et al. [7] and Smith et al. [8] have suggested that in formal education, integrating design thinking into design processes of DF can benefit students' learning. *Design thinking* (DT) is defined as the ability to thoughtfully engage in design processes and knowing how to design, act, argument, and reflect when confronted with ill-defined and complex societal problems [9].

There is a need for teachers who can provide the next generation students with adequate tools to face a rapidly changing,

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unknown future, heavily influenced by computing [10]. However, teachers are not trained to do that, and their inability to give students the required knowledge and competencies can make them feel unempowered. According to Smith, Iversen, and Veerasawmy [11], teachers have insufficient insight into digital technologies and tools for complex problem solving, and they consequently experience loss of authority and control of the teaching.

It has been recognised that there is a need for professional development (PD) of educators when shifting from more traditional disciplines to technological fields and providing competences for confronting and adopting constantly changing, complex processes in 21st society [7,11–15]. This reveals the importance of providing education for teachers to cope with such challenges.

Hence, this paper focuses on methods for empowerment of educators to support their understanding of technologies and enable them to manage DF technologies and utilise DT processes. *Empowerment* can be defined as making people stronger, increasing their self-confidence, ability, and power to control their own life [16]. In this research, empowering teachers means to increase teachers' understanding of technologies in a way that broadens and strengthens their ability to take control of the new, unfamiliar fields of DF and DT within education and to feel confident about applying technologies in their own teaching. Consequently, the aim of this study is to investigate how *development of professional practice can be conducted to empower and support educators to apply DF and DT activities in schools*.

The study examines PD of DF and DT in education in the Danish FabLab@SCHOOLdk organisation. We pursued the aim of the study through five research questions:

(1) How can educators' development of professional practice in DF and DT be conducted?

(2) How does FabLab@SCHOOLdk train educators to apply DF and DT in education?

(3) To what extent does FabLab@SCHOOLdk's PD programmes prepare educators to apply DF and DT in schools?

(4) How does FabLab@SCHOOLdk develop a field of practice in DF and DT in education?

(5) What prevents stakeholders in FabLab@SCHOOLdk from implementing DF and DT in schools?

In order to widen our perspective, we reviewed nine initiatives conducting PD activities in the field of DF and DT. To understand how the FabLab@SCHOOLdk operates, we first identified stakeholders of importance in the organisation. Second, we investigated these stakeholders' experiences and perspectives in relation to the organisation's different ways of conducting in-service teacher training aimed to empower teachers in DF and DT. Finally, we explored possibilities and challenges experienced by the stakeholders when implementing DF and DT into the education.

This study contributes to the research community, by considering the identified challenges that impede educators in teaching by means of design processes in DF [11] and by examining how the suggested framework to overcome these challenges [9] has been realised in the FabLab@SCHOOLdk. Our study revealed that it is not just a question of empowering educators, but that there is a need to consider a wider organism, where different agents support each other in order to realise and conduct systematic PD. The main contribution of this paper is the identification of the important stakeholders when applying DF and DT in schools, the considerations regarding PD in the field of DF and DT, and the discussion of the central gatekeepers' influence on the development processes.

Section 2 examines the concept of PD prior to the presentation of other existing educational initiatives. Research methods and context for empirical investigation are described in the Section 3. Section 4 contains results from the study of the FabLab@SCHOOLdk, while discussion and conclusions are presented in Sections 5 and 6, respectively.

2. Developing professional practice

2.1. Professional development in the field of DF and DT

Professional development (PD) can be defined as development during which individuals acquire a level of competence necessary to operate as autonomous professionals [17]. PD may be conducted through a variety of approaches, e.g. courses, consultations, coaching, communities of practises, mentoring, reflective supervision, and technical assistance.

Valid and valuable PD of teachers is recommended to be continuous, in-depth, driven by teacher needs, and linked to actual teacher practices [18]. PD may be based on different formats such as graduate classes, book studies, workshops, peer coaching, mentoring, professional learning communities, action research, inquiry models, and study groups [19]. Effective kind of PD is where teachers have time to meet, create, craft, and refine lesson plans and teaching units in team-based learning communities [20].

Earlier research identified three important challenges which impact the teachers' possibilities for integrating DF in a design literacy perspective [11].

Challenge No. 1. *Understanding of complex design processes*: According to the authors, teachers are traditionally used to goal-oriented processes where students are working with certain objects, following instructions and using specific tools and materials. They stated that teachers are lacking experience to manage open-ended design processes and find it difficult to support the students with feedback and guide them through their individual ideations and iterations.

Challenge No. 2. *Managing digital technologies and design materials*: Likewise, the authors found that teachers are lacking knowledge and competencies to handle, maintain, and run DF technologies and find it difficult to teach or advise students how to work iteratively with the technologies in order to reflect upon and develop solutions and products.

Challenge No. 3. *Balancing different modes of teaching*: Finally, the authors describe how teachers find it difficult to manage and continuously shift between different roles such as classroom teacher, facilitator of the activities in the classroom, acting as coach for the students and supporting their design processes through reflective questions and dialogues. The teachers were likewise challenged by a loss of control compared to their traditional authoritative expert-teacher role and needed new professional experience to find the courage to let go of control.

To facilitate and support co-development of new teaching practices a three-way structured framework towards training educators to acquire the capabilities identified above is suggested [9]:

1. *Workshops and lectures* using a mixture of literature on DF in education and design literature taught through lectures, group exercises, and preparatory work
2. *In-school-practice* regarding the implementation of a learning design targeted at engaging the students in creating solutions for a given challenge
3. *Peer-to-peer learning* through co-development of learning designs, structured reflection processes around the participants, and collaborative reflections in blogs