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Teaching children digital literacy through design-based learning with digital toolkits in schools

Tilde Bekker*, Saskia Bakker, Iris Douma, Janneke van der Poel, Koen Scheltenaar

Department of Industrial Design, Eindhoven University of Technology, P.O. Box 513, 5600 MB, The Netherlands

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ABSTRACT

The paper presents our work on how to teach digital literacy and design thinking to children at primary and secondary schools, with a particular focus on exploring the tools that may support children's learning in these domains. We have conducted design explorations with input from diverse stakeholders, such as teachers, children, publishers and educational scientists to examine how to develop an integrated design-based learning approach for the school context. Based on the design explorations insights are described about requirements for digital toolkits and the design-based learning process. Based on this work a Reflective Design-based Learning (RDBL) framework is presented that describes the challenges of developing an integrated process that is doable at school, matching teachers abilities, appealing for children and fitting to the knowledge presented in the publisher's materials, that support teaching learning goals as requested by the government.

1. Introduction

How can we teach children about the value of technology through a design-based learning approach with digital toolkits? How can we teach them a problem-solving attitude to life through digital fabrication and design thinking embedded in an educational approach for schools?

The role of digital technologies in everyday life has been increasing over the past decades. As a result, society is changing and it is thus important to appropriately prepare today's children for tomorrow's everyday life. This has resulted in debate about the kinds of skills that children need to be taught. These 21st century skills include critical thinking, creativity, communication, team work, and ICT and information literacy [1]. Different frameworks for 21st century skills have been described, including the KSAVE (Knowledge, Skills, Attitudes, Values and Ethics) framework by Binkley et al. [2]. Binkley et al. [2] distinguish ten skills or competency areas, related to the 21st century skills, grouped into four main categories: *Ways of Thinking* (creativity and innovation, critical thinking, problem solving and decision making, learning to learn/ metacognition), *Ways of Working* (communication, collaboration), *Tools for Working* (information literacy, ICT literacy) and *Living in the World* (citizenship, life and career, personal and social responsibility).

The debate discusses the need for development of both new skills and competencies and emphasizes the importance of lifelong learning, showing that education needs to change to facilitate this. One of these 21st century skills involves **digital literacy**. We broadly interpret digital literacy as the ability to use, understand an evaluate technology, and also to understand technological principles and strategies required to *develop solutions* and realize specific goals [3,4]. This includes providing children with an understanding of the use of various digital technologies, including social media, digital fabrication techniques, sensors, actuators and computing technologies. In our work we have interpreted digital fabrication as a process of designing tangible solutions with digital toolkits.

With the increasing presence of technology in everyday life, we argue it is important for children to get a sense of the value of technology for issues in society. For example, modern communication technologies have the potential to decrease social isolation of elderly, or sensing systems can support people in reducing energy usage in the home. To understand such values of technology, children should not only learn the 'hard' technology skills (e.g. programming and building electronic circuits), but they should also gain insights in how such technologies can impact society. Research has shown that teenagers have different kinds of interest in science, technology, engineering and mathematics (STEM) subjects. A study conducted in the Netherlands in 2010 [5] distinguishes four different profiles of interest in technology: teenagers

* Corresponding author.
E-mail addresses: m.m.bekker@tue.nl (T. Bekker), s.bakker@tue.nl (S. Bakker), i.douma@tue.nl (I. Douma), j.e.c.v.d.poel@student.tue.nl (J. van der Poel), k.j.scheltenaar@student.tue.nl (K. Scheltenaar).

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who are (1) fundamentally interested in STEM, and teenagers with interests in STEM from a (2) career-oriented or (3) human-oriented perspective and those with (4) little or no interest in STEM subjects. These youngsters can be triggered to be interested in technology in different ways, ranging from more fundamental approaches to showing more applied approaches of technology. Gaining an understanding of the value of technology for society, at an early age, is expected to help attract a larger group of youngsters to gain interest in STEM subjects in their future education and career choices, a target that is of increasing importance worldwide (e.g. in European research agenda, Horizon [6] call: SEAC-1-2015). While the concept of digital literacy could also be related to topics other than STEM, we examine it in relation to STEM topics, because within our network of stakeholders (including publishers of educational material, teachers, and educational scientists) that is where it seems to be most easily integrated, providing us with a responsive design research context.

Various developments have already facilitated the introduction of digital tools in the school context to teach children about digital literacy. These include FabLab equipment, such as 3D printers and laser-cutters, but also digital toolkits that support low-threshold 'making' of diverse digital solutions for various problems [7,8]. Examples of digital toolkits, which enable children to engage in digital fabrication of various applications using electronics and programming, include littleBits, lego WeDo and MakeyMakey. Thus, providing digital toolkits with design-based learning opportunities can also be seen as a form of digital fabrication.

However, little is yet known about the requirements for embedding design-based learning of digital literacy skills in a school's curriculum.

In the department of Industrial Design at the University of Eindhoven University of Technology, students develop knowledge, skills and attitude in design related subjects through a design-based learning process of interactive products and systems with societal relevance. Students are taught through various learning activities, which include lectures, but a large part of the learning activities contain design-based learning components. For example, students learn how to apply theories about behaviour change in designing solutions to help people lead a healthier life style. Applying this approach over the last 10 years, we have experienced it supports the development of various 21st century skills; next to digital literacy the approach also enhances collaboration, problem solving, creativity and critical thinking. Therefore we have been exploring whether this approach can also be used in a primary and secondary school context to serve the purpose of increasing children's understanding of the societal relevance of modern technologies, with the ultimate target to increasing children's interests in STEM subjects and careers. Since pupils of primary and secondary school are younger than university level students, one of the challenges in translating this approach is adjusting it to the appropriate level, matching the appropriate learning goals.

To explore how to teach **digital literacy** and **design thinking** to children through a **design-based learning** approach we have conducted various design explorations. Based on both a literature study and these designs explorations, we have developed the **Reflective Design-based Learning (RDBL) framework**. RDBL describes various factors which play a role in developing design-based learning solutions for the school context, taking into account the challenges that come with this formal learning setting. RDBL can be applied to understand the relationships between the various requirements and can be used to create and evaluate solutions for a school context. This paper presents the RDBL framework and illustrate it through three design case studies, which focused on upper primary school (children aged 11–12 years), and lower secondary school (children aged 13–14 years).

The aim of the work presented in this paper is to examine how to integrate elements of instructional settings of design-based learning that teach digital literacy and design thinking in real-life primary and secondary school contexts. Furthermore, it aims to develop a framework for supporting a structured consideration of future RDBL activities for teaching digital literacy and design thinking to children. We focus on the following research question: *How to provide a reflective design-based learning process that supports relevant learning goals from a course specific (e.g. English, Maths and Science) and from 21st century skills perspective (including digital literacy, design thinking and value of technology) in a school context?*

2. The Reflective Design-based Learning (RDBL) framework: overview and grounding in literature

In this section we lay out the motivation for the Reflective Design-based Learning (RDBL) framework, which extends the existing Design-based Learning (DBL) model presented by Gomez et al. [9] by adding a specific Reflective learning component (The 'R' in RDBL) and more attention to the digital properties of the learning environment.

The RDBL framework extends earlier work by Gomez et al. [9], who developed a set of critical elements of instructional settings in Design-based Learning (DBL) in higher engineering education. Their framework, which includes project characteristics, design elements, teacher's role, assessment and social context, was based on an extensive literature review with a focus mostly on engineering disciplines, such as mechanical engineering and electrical engineering. It was used, among other things, to analyse existing DBL activities at engineering level, and to suggest ideas for improving professional development of DBL teachers to redesign their projects using the DBL framework [10]. We examine how it can be extended and applied to a primary and secondary school context.

Based on our experience with design-based learning for industrial design students at the University of Technology, where we apply the Reflective Transformative Design Process (RTDP, Hummels and Frens [11]), the activity of **reflection** forms an important part of the learning process. Therefore, we propose to add this component to the DBL framework for primary and secondary education. The Reflective Transformative Design Process has been developed to combine a flexible design process, with a learning-through-reflection process. It promotes frequently switching between design activities, and to reflect on action when switching between activities. This is in line with the assumption that design processes are not so much rational problem solving processes [12], but rather reflection-on-action processes, as described by Schön [13].

The RTDP is intended for university-level students, and provides a high degree of freedom in how they go through the design process. More structure is needed for younger pupils, at least at first, to guide them through the design process.

2.1. The Reflective Design-based Learning framework

The RDBL framework has been developed by combining input and thoughts from stakeholders (such as teachers, educational scientists, policy makers and publishers) with theoretical grounding in literature. At the start of our research on technology toolkits to teach children digital literacy skills, we organized four workshop-sessions, of roughly two hours each, with various stakeholders (a total of 14 stakeholders were involved). These sessions made us realize that design-based learning in the classroom can only be successful when integrating various criteria coherently into the entire process. For example, digital tools developed as learning materials should be child-friendly and easy-to-use, but also need to be linked to specific learning goals (decided on by governmental policy makers), and the teachers can facilitate the process.