Facilitating Computational Thinking through Digital Fabrication

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ABSTRACT

Curricular changes towards fostering computational thinking through programming for schoolchildren of all ages are spreading rapidly throughout Europe. However, students may not be interested or prepared to engage in programming activities. We propose digital fabrication within a hands-on pedagogical frame as an approach to engage schoolchildren in programming activities facilitating the use and understanding of computational thinking concepts. Within the proposed approach, students engage in programming activities applied to developing tasks from the school curriculum. In this work, we discuss our approach through the experiences gained with pilot trials at a local junior high school. We illustrate the process showing how students get involved and engaged in programming work.

CCS CONCEPTS

• **Social and professional topics → Computational thinking;** • *Social and professional topics → K-12 education*

KEYWORDS

Craft- and project-based pedagogy, computational thinking, comprehensive education

ACM Reference format

1 INTRODUCTION

Computational thinking (CT) has been defined as "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out" [1]. It provides a set of tools to problem solving within computer technology oriented environments [2]. This is a very important skill to acquire as current societies are becoming rapidly more digitalised, and job markets will progressively require such competence [3]. Hence, computational thinking has been called to be incorporated into the school curriculum not only as an integral part of math and science teaching [4] but also cross subjects such as social studies [5] and handicraft education [6] at K-12 level, for instance. CT can be developed through programming activities as the person engages in problem-solving using concepts such as abstraction and composition [7]. However, the introduction of computational thinking through programming alone can face resistance from the students that could have a negatively biased perception towards 'programming' or 'coding' [8]. Pedagogical approaches based on constructivists, hands-on activities could alleviate this problem [9].

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In this work, we explore the students' engagement with creating and programming computer-enhanced artefacts as part of their school subject tasks. The tasks are carried out following a craft- and project-based pedagogical approach based on design thinking and inquiry-based learning. Our contribution poses the benefits of applying digital fabrication within a crafts- and project-based pedagogy as a medium to demonstrate CT relevance through programming and making.

2 RELATED WORK

The work of Bers et al. [9] showed that engaging 4 year olds with construction-based robotics activities fostered their learning of programming concepts and computational thinking. Lau et al. [10] reported on their experience engaging middle school children in hands-on and programming activities through wearable computing, showing that students with no previous knowledge found programming and circuit design enjoyable and interesting. Programming with blocks has been reported to be an effective way to introduce programming concepts to novices. It lowers the learning curve to program, and the students receive immediate feedback on their code: the blocks either click together or the program does not work. (see [11]). This helps novices and children of very young age to get engaged in programming while developing their computational thinking skills [12]. Our work looks at the integration of hands-on constructivist activities through digital fabrication embedded and a craft- and project-based pedagogical approach, to facilitate the engagement in programming and making.

3 PEDAGOGICAL APPROACH

In order to enable the inclusion of digital fabrication and programming into formal education, a solid pedagogical approach is needed [13]. We propose the integration of design thinking and inquiry-based learning in the form of a craft- and project-based pedagogical methodology. This methodology fosters group work and follows a 5 stages process from the *ideation* of a solution; the *planning* of how to achieve it, dividing tasks and assigning roles among group members for instance; the physical *creation* of the solution as an artefact; the *programming* of the artefact to make it interactive; to the *sharing* of their solution and learning experience.

For the hands-on digital fabrication activities we used 3D modelling (TinkerCAD) and 3D printing combined with recycled materials such as pet bottles and cardboards as well as crafting materials such as hot glue, threads, wires, etc. Electronic devices such as sensors, light emitting diodes (LEDs), resistors, etc. are also used to program the interactivity of the artefact. During our pilot trials, the students programmed interactive functionalities to their artefacts using Arduino UNO board. Arduino is an open-source electronics platform based on software and hardware. The Arduino boards are widely used in fabrication labs (*FabLabs*) and *maker* spaces for tinkering and making [14] as well as for education projects [14]. To program and interact with the Arduino board, we use Snap4Arduino visual programming block environment. Snap4Arduino is a modified version of the Snap! visual programming language, an extended implementation of Scratch [14] that allows users to interact with the Arduino board.

4 CT MADE RELEVANT

In our pilot trials, with the assistance of the teacher, students were tasked with the representation of security systems as part of their social studies subject matter. The participating students were from two classes, 9th grade, from a local Finnish junior high school. One class had 13 students (all girls) and the other class had 15 students (3 girls – 12 boys). The students self-organised themselves into groups of 4-5 students in each class. The students have had no previous engagement with programming in particular, or hands-on activities for school subjects in general. Each class was introduced to the basic concepts of programming with blocks in Snap4Arduino environment, electronic components, as well as 3D modelling and 3Dprinting in an introductory hands-on lesson. Students completed a brief questionnaire at the end of their project regarding their views on the craft- and project-based pedagogical approach to digital fabrication and making in their school subject (see Figure 1).

To assist with the ideation process, students were given written information on the different sensors and other electronic components that were available for them to use. During the ideation, the groups came up with several ideas on how to model security in society through their group discussions and teacher's assistance. For example in one class, one of the groups decided to represent security in medieval times, through castle and fortresses. Other groups decided to represent security through secure rooms: guarding a precious stone in a museum and a futuristic sport car in a display room. The students also assigned roles among themselves, as they ideated or while planning what they were to do. Students dedicated a fair amount of time creating and building their models as well as programming the model's interactions. This is understandable as the students (and teacher) were not familiar with digital fabrication, programming, electronics components or hands-on building activities. Although these elements were new and challenges needed to be overcome, students demonstrated commitment and engagement during the creation and programming activities. The students understood the relevance of basic computational thinking concepts such as loops, operators, conditionals, data, etc., when they applied those to their models. For instance, the group representing security through a museum room with a valuable stone, devised a mechanism using pressure sensors, piezoelectric buzzer and LEDs so that when the stone was removed from its spot a visual and audio alarm was activated. All of the groups shared their experiences with their peers and teacher in the classroom at the end of the course. The students' satisfaction with their achievement and engagement in the learning experience was evident by their responses to the final questionnaire, where over 90% of students (12/13; 14/15) indicated that they were more comfortable/confident with programming than before the course.

Figure 1. Craft- and project-based pedagogical approach to digital fabrication in school. Represented here is the process of modelling 'security' in society as part of the social studies subject matter

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