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Investigating primary pupils' attitudes in Makerspace activities through Design-Based Learning

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Outline of the research proposal and theoretical framework.

The current proposal is inspired by the global "maker movement" in education (Halverson & Sheridan, 2014) and it aims to explore primary pupils' learning experiences in digital design and digital manufacturing activities through design-based learning. Maker Movement is as an important and promising development in educational technology (Becker, et al., 2018). It is a constructionism learning approach (Keune & Peppler, 2019) and it has the potential to support active participation in learning, facilitate *bildung* (deep and sustained learning) and promote skills acquisition, students' agency, collaboration, creativity and innovation (Bevan, 2017; Katterfeldt, Dittert, & Schelhowe, 2015). The Maker Movement is gaining growing interest and can raise key questions in school curricula and educational policies in Europe as well (Rosa, et al., 2017; Howard, Gerosa & Mejuto, 2014). While digital design and digital manufacturing have been extensively used in tertiary education, supporting learning in variety of subjects (anatomy, dentistry, geosciences, chemistry, arts), few studies exist in the context of primary and secondary education (Ford & Minshall, 2019). The current study aims to fill this gap by investigating the impact of digital design, 3D printing and laser cutting activities on primary pupils' motivation and acceptance. Moreover, the study aims to explore how these activities affect students' attitudes toward Science Technology Engineering and Maths (STEM) subjects and careers. Specifically, our project aims to answer the following questions:

RQ1: What is the impact of digital design and digital manufacturing on primary pupils' learning satisfaction and enjoyment?

RQ1: What is the impact of digital design digital manufacturing on primary pupils' perceived usefulness and perceived ease of use?

RQ3: What is the impact of digital design and digital manufacturing on primary pupils' attitudes towards STEM subjects and careers?

The study draws on the Cultural Historical Activity Theory (CHAT) developed by Engeström (1999). The CHAT framework describes an Activity System as a triangle where the sides represent the Subject, Object and the Community while the corners represent the mediation artefacts to those relationships (Tools, Social Rules and Labour Division). Typically, a Subject (learner) is trying to achieve a purpose or an Object (e.g. a 3D printed object) or leading to an Outcome (enjoyment and satisfaction, attitudes, interest development), within a Community. The activity is mediated by tools (e.g. digital design software, 3D printing and laser cutting facilities), it is organised by a system of social rules (class environment) and involves a Division of Labour e.g. (teachers and FabLab support). The activity is a dynamic entity where transformations constantly happen making the different elements of the Activity System to interact with each other (Kuutti, 1996).

We have used the Activity theory in order to understand the context of digital design and digital manufacturing. Our objective is to gain insights into how participation in a design-based makerspace activities influence students' enjoyment and satisfaction, perceived ease of use and perceiver usefulness and interest towards STEM. While studies exist in the secondary and post-secondary level, less is known about their implications in elementary school contexts.

Methodology

Participants were 13 pupils (6 girls and 6 boys, 10 to 11 years old) recruited from a local primary school. The study granted ethics approval from the University Ethics Committee. The teaching intervention lasted for 6 weeks, during November and December 2019. Once a week, with the guidance of an experience technology teacher, pupils participated in a three-hour session on digital design, 3D printing and laser cutting activities. The activities carried out in the school computer lab and in the University Fabrication Laboratory (FabLab). A design Based Learning (DBL) approach was adopted.

Design Based Learning is a problem-based project-based learning approach that focuses on working with the design of artefacts, solving real life problems and promoting critical thinking and creativity in order to acquire engineering domain knowledge (Gómez Puente, van Eijck, & Jochems, 2013). Students introduced to the basic principles of a Computer-Aided Design (CAD) online tool (Tinkercad) and then they built their creations (e.g. key rings, Christmas decorations or other objects of their choice) using the laser cutting and 3D printing facilities of the FabLab. During the design-based learning procedure, students had the opportunity to develop their ideas, design, build and test their prototypes, discuss and provide feedback to each other, and re-design and re-build when needed.

To evaluate the impact of the digital design and manufacturing on students' attitudes, a mixed study approach has been employed. Students completed a questionnaire on their perceived level of learning satisfaction, enjoyment, perceived usefulness, ease of use and their attitudes towards STEM.

Questionnaire items were adopted form previous studies: for enjoyment, perceived ease of use and perceived usefulness from Venkatesh et al. (2003) on technology adoption, for satisfaction from Deci and Ryan (2002) on motivation and for STEM interest from Tandra, et al. (2010) on Interest in STEM Careers. To ensure reliability and validity, Cronbach's alpha test and principal components analysis were performed.

Moreover, focus group interviews with the students were conducted twice throughout the six-week making intervention. The interview questions were designed to elicit more information on the different aspect of students' motivation, technology adoption and their interest towards STEM subject and careers, as an outcome of the activities in relation to the mediating artefacts (digital design, 3D printing and laser cutting). A deductive content analysis aims to search for evidence on the impact of the making activities on motivation, acceptance and interest development towards STEM. Further analysis on the impact of the other elements (community, rules and division of labour) is the next step.

Conclusions, Expected Outcomes or Findings

The analysis is still ongoing. However, preliminary results revealed that a few patterns emerge. Students' learning satisfaction and enjoyment were reported high during the digital design and manufacturing activities. Also, students agreed that these activities can improve their performance in science and technologies (high level of perceived usefulness) and found these activities to be easy for them (high level of perceived ease of use). Students also reported that their participation in the digital design and manufacturing activities had a positive impact in the development of their interest towards STEM subjects and careers.

Initial findings are in line with previous results from the related literature (Papavlasopoulou, Giannakos, & Jaccheri, 2017). Making creates new opportunities for learning through new technologies (e.g. 3D printing) and fosters students' learning motivation and interest towards STEM.

The current study proposes a design-based learning approach in the context of the makerspaces movement in primary education. Also, it provides extra evidence for the importance of integrating maker activities in school curricula and especially in the primary context. Moreover, considering the declined student interest towards STEM subjects and careers from one site and the growing demand in Science and Technology jobs (in Europe and worldwide) from the other (Kearney, 2016), the study addresses also the issue of how digital design and manufacturing in primary education can help students to develop their interest towards STEM.

Better understanding of pupils' motivation and attitudes in the context of the "maker movement", can help education professionals (teachers, researchers, instructional designers and policy makers) to design and deliver higher quality STEM courses in order to better support successful learning.

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