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3D printing as a means of learning and communication: The 3Ducation project revisited

Alekos Pantazis, Christina Priavolou *

Department of Innovation and Governance at Tallinn University of Technology, P2P Lab, Tallinn University of Technology, Akadeemia tee 3, 12618 Tallinn, Estonia

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ABSTRACT

This research project explores to what extent the utilization of open-source 3D printers and 3D design software could serve as means of learning and communication. The principles of non-formal education aligned with the concept of constructionism are used to create an experimental educational scenario focused on geocultural tourism for persons with visual impairments. This paper documents our experience and presents our findings from a 25-day long project, which took place in Zagori, northwestern Greece. 11 high school students from Portugal designed and manufactured natural and cultural heritage artifacts carrying messages in the Braille language. The objects were then handed to people with visual impairments with a twofold aim. First, to enable the communication among persons with and without visual impairments; and, second, to empower students to participate in training projects through open educational procedures. We conclude that open educational practices can boost students' active engagement in educational processes. Finally, 3D printing encourages a meaningful communication among people with and without visual impairments via the tangible exploration of geocultural components.

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1. Introduction

The development of learning theories and practices globally justify their characterization as objects of extensive research. Social and collective processes within teaching procedures are currently targeted to alienate the hierarchical constraints of knowledge production (Kemmis and McTaggart, 2005). Student-centered approaches, including the constructionist learning theory and open, non-formal educational practices, are used as means to facilitate student's active involvement in learning (Blikstein, 2013). Moreover, the integration of 3D printing technology in teaching inaugurates new ways of personal expression, fostering students' creativity and experimentation (Huang and Lin, 2016).

This paper focuses on the implementation of an educational scenario of non-formal education aligned with the concept of constructionism. It builds upon a critical making research project, which took place in two Greek high schools (Kostakis et al., 2015). The main goal of this paper was to explore how 3D printing can electrify various literacies and creative capacities of students.

In the context of our project held in Zagori, northwestern Greece, 11 Portuguese students manufactured 3D printed bridge and canyon artifacts of the local region handed to persons with visual impairments. This work attempts to explore to what extent open-source technologies and 3D printing could serve as a means of learning and communication among persons

* Corresponding author.
E-mail address: cpriav@ttu.ee (C. Priavolou).

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with and without visual impairments. The educational scenario was then presented to Greek educators with the aim to discuss our findings and trigger awareness of the application of open educational practices in teaching.

As far as the structure of this article is concerned, a short review of the corresponding theoretical background is presented. The methodological part follows with a description of our methodology and research questions. Then, we narrate and discuss our findings from both students' and educators' perspective. Finally, we summarize our conclusions and culminate with suggestions for future research.

2. Theoretical background

In the framework of developmental psychology, Rousseau's invention of childhood provided a breakthrough in the research field of education (Boone, 2017). Thenceforward, contemporary educational practices have been treated with skepticism, while the need for democratic education has been recognized (Soomro et al., 2010). Bearing in mind the fact that our networked world impinge on the way that societies are organized, educated and developed, alternative ways of transforming the educational landscape have been explored (Kemmis and McTaggart, 2005).

Towards this goal, international communities are moving towards non-formal education settings. The concept dates back several decades and differs from formal and informal learning. Formal learning focuses on hierarchical, teacher-centered approaches and promotes standardized, academic knowledge production (Ngaka et al., 2012). On the other hand, informal education refers to incidental accumulation of experience or skills deriving from daily life and interaction with the environment (Dib, 1988). Non-formal educational practices, located somewhere in the middle of the two above-mentioned concepts, are open, innovative and adaptable to the changing conditions and individual needs.

Aiming to drift apart from schooling as a prevailing way of learning, non-formal education attempts to make knowledge accessible to those who are not enrolled in schools (Yasunaga, 2014). The main purpose of non-formal practices is not certification but the acquisition of knowledge and skills through participation, observation and communication (Souto-Otero et al., 2013). The content of a non-formal educational procedure is basically practical, while its delivery modes remain flexibly structured. Non-formal educational programs are usually small-scale, short-term and entail specific purposes.

Despite the non-negligible potential of non-formal education, concerns about its effectiveness have been raised. The short duration of non-formal programs in combination with their preclusion of broader national education may create the impression that, unlike formal, non-formal education is insufficient (Yasunaga, 2014). However, having realized the importance of gaining knowledge outside institutions, the conjunction of the different educational types matters rather than their counterpositioning (Rogers, 2004, p. 234). Thus, non-formal education could be viewed as complementary, supplementary and/or alternative to formal education, which enhances social cohesion and individual capabilities (UNESCO Institute for Statistics, 2012).

In an effort to increase the possibilities for effective learning through experience, non-formal educational settings are correlated with the concept of constructionism. The development of the constructionist learning theory by Seymour Papert (1980, 1993) was an important movement towards the active involvement of students in education. In the vein of many prominent scholars in the educational philosophy (for example Maria Montessori, Lev Vygotsky, Paulo Freire or John Dewey), Jean Piaget developed the constructivist learning theory, which defines learning as "building knowledge structures". Constructionism extends the idea of constructivism by constructing and publicly share objects via conscious and felicitous actions (Papert and Harel, 1991, p.1).

Instead of making deposits of information into their minds, students interact with the environment and gain knowledge rooted in their experience (Ackermann, 2001). Students build objects rather than consume knowledge, being involved in hands-on explorations which boost their experience and inventiveness (Papert, 1993; Ackermann, 2001). An indirect impartation of knowledge occurs combined with collaborative and social activities that accompany the educational procedure. Considering the tight relationship between education and social values, a collective learning process could lead to a culture of sharing and open collaboration (Temple and Moran, 2011, p.195; MacDonald, 2012).

Beyond traditional educational approaches, where students could not see themselves as makers, constructionism provides the appropriate context for collaboration, communication and creative learning. Students engage vigorously in the discovery of solutions especially in meaningful problems, which enhance the educational outcomes (Cavallo, 2000). Within such an environment, teachers act as eager facilitators who consult students and race against the school bell with the aim to spur learners' self-motivation.

To achieve the full potential of constructionism the importance of students' participation emerge. Attracting students' interest plays a vital role in the rise of positive outcomes, taking into account students' inner incentives for learning beyond competition (Wadsworth, 1998). In an attempt to satisfy students' need for communication and collaboration, discussions around the utilization of technology in teaching arose.

In the framework of constructionism, Papert, as an enthusiastic proponent of technology, pioneered the penetration of digital tools in learning institutions (Blikstein, 2013). Since the 1980s, Papert spread the powerful ideas of the Logo programming language and made robotics accessible to children. Information and Communication Technologies (ICT) were acknowledged as tools able to construct personal experience, enable human interaction and manufacture powerful artifacts within self-driven educational settings (Schelly et al., 2015).

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