Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece

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Vasilis Kostakis [1],*, Vasilis Niaros [2], Christos Giotitsas [3]

P2P Lab, Tallinn University of Technology, Akadeemia tee 3, 12618 Tallinn, Estonia

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ABSTRACT

This research project attempts to examine to what extent the technological capabilities of open source 3D printing could serve as a means of learning and communication. The learning theory of constructionism is used as a theoretical framework in creating an experimental educational scenario focused on 3D design and printing. In this paper, we document our experience and discuss our findings from a three-month project run in two high schools in Ioannina, Greece. 33 students were tasked to collaboratively design and produce, with the aid of an open source 3D printer and a 3D design platform, creative artifacts. Most of these artifacts carry messages in the Braille language. Our next goal, which defined this project's context, is to send the products to blind children inaugurating a novel way of communication and collaboration amongst blind and non-blind students. Our experience, so far, is positive arguing that 3D printing and design can electrify various literacies and creative capacities of children in accordance with the spirit of the interconnected, information-based world.
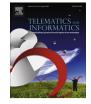
1. Introduction

Three-dimensional (3D) printing – actually a subset of additive manufacturing – is, in short, the process of joining material, layer-by-layer, to make objects from 3D model data (usually created by a computer-aided design software or a scan of an existing object), in contrast to subtractive manufacturing technologies (ASTM, 2010). This technological capability has been around for more than three decades and has been known as the "rapid prototyping machine" (Bradshaw et al., 2010; Campbell et al., 2011). It was called "rapid" because one-offs could be made more easily and quickly than by the conventional numerically-controlled machines and it was called "prototyping" because it was too slow and expensive to be used for production (Bradshaw et al., 2010). For example, an architect could print in 3D the design of a building or an automobile engineer could print a prototype of a part from the car for further refinement of the design. However, lately 3D printers have been adopted, especially by aerospace and health care industries (Bullis, 2011), to make functional products as well, whereas the rise of relatively low-cost (€500–1300), open source desktop 3D printers, such as RepRap or Ultimaker

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* Corresponding author.
  E-mail address: vasileios.kostakis@ttu.ee (V. Kostakis).

  [1] Vasilis Kostakis (PhD, MSc, MA) is a political economist and founder of the P2P Lab. Currently he is a research fellow at the Tallinn University of Technology and a collaborator of the P2P Foundation.
  [2] Vasilis Niaros (PhD student at the Tallinn University of Technology) is an urbanist interested in investigating the relationships of technology, education, culture and urbanism. He is also a research fellow at the P2P Lab.
  [3] Christos Giotitsas is a junior research fellow at the P2P Lab.

(Kalish, 2011) have given the chance to hobbyists and adopters of the do-it-yourself culture to experiment, design and produce things moving gradually from "prototyping" to "manufacturing". Moreover, it becomes evident that this Commons-oriented, open source, collaborative experimentation with 3D printing has arguably dropped the costs and improved the user-friendliness of 3D printing hardware and software making this technology more accessible than ever, even to schools and young students.

This article is part of an ongoing research project that tries to tentatively examine to what extent and degree the technological capabilities of 3D printing could serve as a means of learning as well as a way of meaningful communication amongst blind and non-blind students. This paper, which describes the first phase of this project, focuses on open source 3D printing, within the context of two high schools based in Ioannina, Greece, with particular reference to possible applications for learning. In total 33 students from one public and one private high school were called to collaboratively design and produce, with the aid of an open source 3D printer and a 3D design platform, functional artifacts of their own choice. Students were told that those artifacts, from stamps, cups and sharpeners to sophisticated toys, carrying messages in Braille language, would be sent to blind fellow students.

Within the framework of constructionism we attempted to run our experimental project, document our experience, discuss our findings and create an educational scenario in a narrative format that could be used, tested, criticized, enriched and, hopefully, improved further. This paper begins with the formulation of our research questions as well as a brief review of the relevant theoretical background. The methodological part follows with a description of our educational scenario as well as some information on the schools where the project took place. We, then, discuss our experience through students' creations concluding with recommendations for future research.

2. Research questions and theoretical framework

Nowadays students have grown up in a framework of constant connectivity and interactive culture and, thus, may have different attitudes and understandings of concepts such as creativity, collaboration, communication and sharing (see only Prensky, 2001, 2007; Rushkoff, 1996; and for a critical approach to the "digital native" concept see Bennett et al., 2008; Bennett and Maton, 2010). This behavior should have arguably led to reforming the institutions of learning and education. Since the 1980s, Seymour Papert (1980a,b, 1993, 1997), father of the LOGO programming language and key developer of constructionism, has been arguing that the social penetration of information and communication technologies (ICT) provides individuals or communities with the means to develop and to implement new educational ideas. However, as Papert (1997) points out discussing the penetration of computers in schools, learning institutions resist the reform by appropriating or assimilating it to their own structures.

The main research question that guides our inquiry could be formulated as follows: What role could 3D printing and design, along with the modern ICT, play in developing and implementing new educational ideas based on the principles of constructionism? Therefore, from the aforementioned question a few sub-questions emerge: What kind of educational environments could be created, fused with the values of collaboration and meaningful communication which are pillars of the Commons-oriented, open source movement (as it is explained later)? Could these scenarios and environments be considered as "objects-to-think-with" (Papert, 1993, p. 182), which would contribute to the social process of constructing the education of the future? And last but not least –actually this was the main concern of the teachers, Christos Bitsis and Loukianos Xaxiris, who participated in this first phase of our project– could such a media-based knowledge acquisition contribute to the solution of problems observed in these high schools, i.e., lack of students engagement (personal communication with Bitsis and Xaxiris, April, 2013); theoretical teaching and textbook based instruction (personal communication with Bitsis, Xaxiris, April, 2013); poor demonstration infrastructure available (personal communication with Bitsis, Xaxiris, April, 2013); and students' misconceptions about project-based learning (personal communication with Bitsis, Xaxiris, April, 2013). Regarding the latter point, it would be interesting to mention that although students were unanimously for a hands-on, practical mode of learning they seem to highly underestimate the project-based courses held so far in their schools (questionnaires and personal communication, 2013).

To tackle these questions we choose to develop our educational scenario based on the learning theory of constructionism developed by Papert (1980a,b, 1993, 1997), Papert and Harel, (1991) and informed by Ackermann (2001), which emphasizes the personalized production of knowledge artifacts as well as the social nature of the learning process:

> constructionism – the N word as opposed to the V word – shares
> constructivism's connotation of learning as "building knowledge structures"
> irrespective of the circumstances of the learning. It then adds the idea that this
> happens especially felicitously in a context where the learner is consciously
> engaged in constructing a public entity, whether it is a sand castle on the beach
> or a theory of the universe (Papert and Harel, 1991, p. 3).

Similar to many prominent scholars in the philosophy of education (for example Jean Piaget, Lev Vygotsky, Paulo Freire or John Dewey) constructionism maintains that students' intellectual growth must be rooted in their experience (Papert, 1980b). Knowledge is not seen as a commodity to be transmitted but as a personal experience that has to be constructed