Chapter 4
A Cloud Platform for Sharing Educational Digital Fabrication Resources Over the Internet

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ABSTRACT

Cloud and IoT technologies have the potential to enable a plethora of new applications that are not strictly limited to remote sensing, data collection, and data analysis. In such a context, the IoT paradigm can be seen as an empowering technology rather than a disruptive one since it has the capability to improve the standard business processes by fostering more efficient and sustainable implementations and by reducing the running costs. Cloud and IoT technologies can be applied in a broad range of contexts including entertainment, industry, and education, among others. This chapter presents part of the outputs of the NEWTON H2020 European project on technology-enhanced learning; more specifically, it introduces the concept of fabrication as a service in the context of educational digital fabrication laboratories. Fab Labs can leverage cloud and IoT technologies to enable resource sharing and provide remote access to distributed expensive fabrication resources over the internet. Both platform architecture and impact on learning experience of STEM subjects are presented in detail.

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INTRODUCTION

Formal education, vocational training and lifelong learning play an increasingly important role in society.

These are seen not only as means to providing benefits in terms of enabling future economic development, but also as a way to offer people support for acquiring new skills and knowledge, and to foster personal and professional development. At any moment, worldwide, millions of citizens of all ages benefit from diverse forms of education. This education is mostly *formal* (i.e. in schools, universities), but also *non-formal* (i.e. outside the education system) and *informal* (i.e. individuals are responsible for their education). However, regardless of education type, the interest in pursuing a scientific education is experiencing a negative trend among the younger generations of most developed countries (Murray, 2016). For instance, in Europe alone, the proportion of graduates specializing in science, technology (e.g. computing), engineering and mathematics (STEM) has reduced from 12% to 9% since 2000 and consequently Europe is facing a concrete shortage of scientists (Convert, 2005).

The disengagement starts during secondary education and it is mainly due to two factors:

1. Students perceive scientific subjects as difficult, and
2. they regard science-related careers as little attractive in terms of job quality-pay level balance.

Many efforts are put worldwide trying to reverse this process, including part of large European Union projects such as NEWTON[1]. The goal of the NEWTON project is avoiding early student dropout from the scientific stream; for this reason it is mainly targeted to primary and secondary school students. NEWTON aims at developing student-centered non-formal (i.e. outside the education system) and informal (i.e. based on self-learning) teaching methodologies that leverage the latest innovative technologies to deliver more effectively learning content and make STEM subjects more appealing. In such a context, Fab Labs have been proven to be an innovative and effective teaching tool to attract students to STEM subjects (Gershenfeld, 2012; Blikstein, 2013; Togou, 2019).

A Fab Lab is a novel laboratory concept developed at the Massachusetts Institute of Technology (MIT); it is a small-scale workshop with a set of flexible computer-controlled tools and machines such as 3D printers, laser cutters, CNC (computer numerically controlled) machines, printed circuit board millers and other basic fabrication tools which, usually, are not easily accessible. Fab Lab technology enables the implementation of student-centric teaching and learning techniques based on experimentation and "learning by doing". This is why a Fab Lab attracts students as they can experiment and materialize their ideas in engaging and stimulating ways. Unfortunately, a major limitation of current Fab Labs is their lack of external connectivity and infrastructure flexibility, requiring constant human supervision. Additionally, the costs necessary to deploy a minimum Fab Lab infrastructure compliant with the MIT specifications can be as high as $250,000 and not all the institutions (especially primary and secondary schools) can afford such a huge expense. This is indeed a great barrier to the worldwide diffusion of Fab Labs. In order to overcome this shortcoming, we propose a cloud-based framework that can enable academic institutions which cannot afford to setup their own Fab Labs, to access existing Fab Labs (i.e. Fab Labs deployed in different locations worldwide) through the Internet. We have called this new concept Fabrication as a Service (FaaS). The ubiquitous access provided by the FaaS infrastructure is a necessary evolution of the Fab Lab concept and is necessary to foster the adoption at a larger scale of digital fabrication and experimentation through prototyping as an integral part of the twenty-first-century teaching and learning paradigm. Moreover, FaaS democratises access to Fab Labs by making