3D PRINTING ONLINE LEARNING ENVIRONMENTS: MULTIPLE APPROACHES TOWARDS SELF-LEARNING OF ENGINEERING DESIGN STUDENTS

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Abstract

This paper presents an exploratory study conducted at two Higher Education Engineering Schools, namely in the Lapland University of Applied Sciences (Finland) and in the Polytechnic Institute of Castelo Branco (Portugal), with the aim of constructing digital learning environments that promote increasing learning autonomy to students working with 3D printing technologies in engineering design. Based on pilot blended learning experiences carried-out in both schools, new instructional design solutions are proposed and discussed, aiming at a widespread use of such digital platforms not only for blended and online learning processes in engineering schools, but also as Massive Open Online Courses open to wider communities interested in such technologies.

Keywords: Engineering Education, 3D Printing, Blended Learning, Online Learning, MOOCs.

1 INTRODUCTION

The widespread technology use among current higher education and engineering students has made educational institutions worldwide acknowledge the need of incorporating it in teaching and learning for explicit reasons [1]. Nonetheless, some authors refer that the use and role of digital technology in higher education is contested [2], making it important to reflect on what extent the total availability of Information and Communication Technology (ICT) learning tools is effectively promoting increased learning outcomes. Considering that current higher education students may be considered digital natives [3] due to the fact that most of them have grown up in a framework of constant connectivity and interactive culture, it can be assumed that they are better prepared to learn and work using digital learning tools.

An important type of such learning tools are the Online Learning Environments (OLE) as they incorporate digital tools and resources to support learning, applying information and communication technologies to different education processes [4], [5]. Such education processes may be categorised as blended learning or as online learning, taking into account the OLE type of use on the teaching & learning processes. Blended learning courses usually use OLEs to support face-to-face methodologies as they can have from one third to almost 80% percent of the content delivered online [6]. According to the same authors, online courses can be classified as such when the web-based content is higher than 80%. Online learning methods use the OLEs mainly to enhance autonomous learning with multi-way communication between students and lecturers. Nonetheless, such classification may also be considered insubstantial as teaching & learning depend mainly on the process rather than on the materials, or the way they are conveyed. Finally, a course can be classified as traditional when absolutely no web-based contented is delivered, and as web-facilitated when online content is used, but is lower than that of blended courses [6].

As stated above, OLEs incorporate digital tools and resources to support the learning process, offering students cumulatively online delivery of information, communication, education and training. Considering that OLEs are relatively recent tools, when compared to traditional teaching & learning methodologies, the necessary redesigning of the related learning spaces turns out to be unavoidable [7]. Therefore, dedicated instructional design methodologies and related E-strategies are needed to promote and effective and efficient use of the OLEs in the teaching & learning processes of current higher education students. A particularly challenging context is associated to science, technology, and engineering (STE) education, as related domains often require laboratory exercises and tasks to provide effective skill acquisition and hands-on experience. ICT teaching & learning tools show to be difficult to use particularly when online distance learning is required, as either the physical laboratory has to be enabled for remote access or it needs to be replicated as a fully software-based virtual laboratory [8]. New emerging technologies are being developed to assist the tackling of such
challenge, conveying dedicated methodologies likely to have an impact on learning, teaching, and creative inquiry in education [9]. One of such recent proposals are the inverted classrooms, also known as flipped classrooms.

Flipped classrooms are a pedagogical approach through which typical classes and members are inverted [10], [11]. Small video-classes are watched by the students at home, previously to class, and class' time is dedicated to exercises, projects and discussions. The class' video is the key component of the flipped approach and is created and made available by the teacher online. Even though there is not a unique model for the flipped classrooms – the term is used to describe almost any class' structure that provides pre-recorded video-classes followed by face-to-face exercises. Such methodology shows to be particularly appealing to ICT teaching & learning, as it allows using OLEs to support students autonomous work, thus contributing to the students and teacher's motivation.

A particular case of ICT teaching & learning processes is related to the new additive materialization and manufacturing processes, also known as 3D printing [12]. 3D printing is a rapidly growing area of technology providing flexible manufacturing method, which deviates from conventional manufacturing based on material subtraction. The additive manufacturing process starts from desired 3D CAD model, which is sliced with separate slicing software into layers. These layers are then used for writing the necessary code for the 3D printer itself including all the necessary parameters. The device prints the object layer by layer according to used technology. For example, material extrusion, which is the most popular 3D printing technology measured by commercial numbers, extrudes molten plastic filament layer by layer through nozzle in the equipment forming the desired object [13].

Considering the significant economic and societal implications envisaged in a near future for 3D printing and additive manufacturing [14]–[16], much effort has been put into the teaching & learning of such ground-breaking technologies and processes, namely using differentiated spatial ability teaching models [12], developing open source 3D printing as a means of learning [17], or by means of a self-learning approach using multimedia and augmented reality resources on mobile devices [18], just to mention a few. Nonetheless, the availability of online learning solutions that may allow the user's self-learning experience without focusing on a specific commercial solution, or in a specific 3D printing brand is still lacking.

Recently, Massive Open Online Course (MOOCs) emerged as a popular mode of learning, as these courses are available online for free and without any limit of participants. MOOCs can be classified as massive courses which have a global reach, unlimited attendance, and open access over the internet via a combination of social networking and video podcasts [19]. These web-based courses were first introduced in 2008 and gained special relevance in 2012 as several providers associated with top universities offered a wide variety of courses, with special relevance to science, technology, and engineering education provided by MIT developed MOOCs. On what concerns to 3D printing teaching & learning MOOCs, even though some pilot courses have started to be available to the general public, the truth is that they are too focused in a dedicated solution, or method, not allowing, therefore its widespread use to a wide range of software and brands, requiring an additional effort to generalise such courses to incorporate the characteristics of universal self-learning of non-branded 3D printing software and applications.

2 MATERIALS & METHODS

This report refers to an exploratory study conducted at two Higher Education Engineering Schools, namely in the Lapland University of Applied Sciences (Finland) and in the Polytechnic Institute of Castelo Branco (Portugal) with the aim of constructing digital learning environments that promote increasing learning autonomy to students using 3D printing technologies in engineering design. Hence, dedicated strategies and resources were allocated to such research in order to accomplish the exploratory study envisaged goals. Such process went through a two-stage experiment, with the first phase taking place at the Lapland University of Applied Sciences.

2.1 THE PROJECT @ LUAS

Lapland University of Applied Sciences (LUAS) is situated in northern Finland providing education in areas the of Industry and natural resources, Social services, Health and Sports, Business and culture and also in Travel and tourism. LUAS has around 5000 students and 500 employees and it consists of three campuses situated in Rovaniemi, Kemi and Tornio. LUAS part of this study was conducted in the Mechanical engineering degree situated in the Unit of Technology in Kemi [20], [21].
Lapland University of applied sciences the unit of Technology in Kemi, Finland acquired six 3D printers that were based on material extrusion, more detailed in FDM-technology. The goal was to build up a learning environment in which the students could learn the basics behind 3D printing technology and perform practical printing exercises with the equipment. A pilot course was held in spring 2017 from 3D printing to mechanical engineering students. The structure of the learning consisted of following parts:

1. Introduction to the 3D printing technology (guided)
2. Introduction to the equipment (e.g., usage, safety, etc.)
3. Practical printing exercises (guided and independent)
4. Independent learning of the technology through online platforms and environments

In the pilot course, learning leaned heavily on blended learning as the students were constructing their own learning while the teacher functioned as a support for the whole process. The target group was <10 students so the tutoring was kept as efficient as possible. The background knowledge required to handle the printing event consisted of basic design aspects for traditional engineering design but also for DFAM (Design for Additive manufacturing). This part used Moodle platform for knowledge distribution and also selected online platforms and sites for giving fresh information and insight to 3D printing.

A model for the components of learning was created and it was called the active learning model. Model of the active learning can be seen in figure 1.

![Figure 1. Active learning model at LUAS technology](image)

Students learned the basics of 3D printing through two consecutive learning assignments from which the first introduced the theory and knowledge behind 3D printing. The second assignment concentrated to actual design process for printable object and to the practical printing. As a result, the students learned the whole process behind 3D printing and especially FDM technology [22].

2.2 The project @ ipcb

The second stage of this pilot experiment will take place at the Polytechnic Institute of Castelo Branco (IPCB) in the first semester of the 2017/2018 school year. The IPCB is located in the centre of Portugal and is constituted by six different schools, dedicated to agrarian sciences, arts, education, health, management and engineering. The IPCB, as of 2016, had circa 4000 students and 600 employees [23] and has four campuses situated both in Castelo Branco and Idanha-a-Nova.
IPCBr’s part of this study was – and will be – conducted in the Industrial Engineering degree of the engineering school located at the Talagueira Campus. In order to prepare the students for the 3D printing learning procedures that took place in the spring semester of 2017 at the ULAS campus, dedicated intercultural communication skills were developed based on 3D printing content and language learning. Such preparation took place during the 2015/2017 school years. More detailed information on the subject can be found on Gaspar et al [24].

On the 2017/2018 school year it is envisaged that the full replication of the practical experiment will take place at the IPCB with selected students of the Industrial Engineering degree. Such replication will be based on the processes and procedures of the first phase that took place in the ULAS campus in the preceding year, which were stated in the previous section of this text.

3 RESULTS

Pilot learning experience at LUAS in the spring semester 2017 presented the requirements and the need for future development of the OLE and the students’ autonomous learning processes.

Firstly, 3D printing presented to be efficient way to promote new technology to engineering students since the technology itself is very appealing. The foundation was always kept in the own needs of the student so he/she could learn, design and print something for him/herself. The important parts were noticed to be:

1. The assignments have to start from the own needs and expectations of the students, as this increases their motivation;
2. There must be open access to the printing equipment for the students, as this promoted particularly the independent work of the students and, as a consequence, lead to a lesser dependency on the teacher;
3. Sufficient support must be given for the student on the behalf of the teacher.

Secondly, attention must be paid to the knowledge used in the learning process and especially to the method for learning. Blended learning offers a good way to incorporate modern OLEs into face-to-face learning processes, in which the traditional lecturing is replaced by supporting the learning path of the student. As more freedom is offered to the student, it enables multiple environments such as educational facilities, digital platforms and also personal spaces. In this study it was noticed that the student even continued to post-process the 3D printed object at home in their own time. The important parts were noticed to be:

1. Quality of the used learning platforms, which results in suitable and modern online learning platform;
2. Variety and diversity of different learning environments, as when the learning is motivating and diverse, the student continues the learning experience in his/her own time;
3. Traditional lecturing is replaced by supporting and tutoring the students, enabling new ways for the students to function and increase their autonomy by themselves.

On what concerns to the intercultural communication preparation based on 3D printing learning of content and language that took place during the 2015/2017 school years, it was found that such approach enabled students to improve not only their knowledge on the specific content, but also their language proficiency and cognitive processes in English. A tangible result of the cooperative learning, in which students and teachers were engaged, was the compilation of a glossary on 3D-printing to be used and further developed by the students and the lecturers of the IPCB and the ULAS alike.

Following both stages of this pilot experiment on the development of dedicated OLEs to promote increasing learning autonomy of students working with 3D printing technologies in engineering design, Massive Open Online Courses on such topics are envisaged to be developed collaboratively by the students and lecturer teams of both Finnish and Portuguese engineering schools.

4 CONCLUSIONS

Based on pilot blended learning experiences carried-out in the Finish Lapland University of Applied Sciences and the Portuguese Polytechnic Institute of Castelo Branco, new instructional design solutions were proposed and discussed, aiming a widespread use of online learning environments to
aid engineering design students using additive manufacturing technologies, namely 3D printing and fused deposit modelling.

As further developments, Massive Open Online Courses open to wider communities interested in such technologies are expected to be developed collaboratively by students and teachers of both engineering schools.

REFERENCES


