AUGMENTED REALITY AND DIGITAL FABRICATION TECHNOLOGIES AS ASSISTIVE TOOLS FOR UNIVERSITY STUDENTS WITH DISABILITIES

C. Lorenzo, E. Lorenzo

CEU University (SPAIN)

Abstract

While during the last years universities have been embracing digital fabrication technologies in engineering, design and architecture departments, there remains a lack of provision for the students with special needs. The premise for our work is to provide disabled students with these technologies to be competitive in the job market, as well as to have access to the same opportunities as other students. This paper describes a case study carried out at Fab Lab Madrid CEU, the digital fabrication laboratory based at CEU University. It targets the use of augmented reality and digital fabrication as support technologies for students with disabilities to teach universal design in the college classroom.

Augmented reality can be viewed as an assistive technology, due to its potential to minimize the effects of a disability and provide an alternative means to accomplish a particular task. It also helps in social interaction and communication. Digital fabrication laboratories (Fab Labs), on the other hand, place an emphasis on the social aspects of the space and benefits from these environments on students with disabilities are proved. Fab Lab users build confidence and engage with other people while developing technical skills.

The case study will show the impact of the combination of both, augmented reality and digital fabrication technologies, as assistive tools for university students with disabilities. It will also show the benefits of the NEWTON Project platform, an innovative tool that allow students remote access to digital fabrication machines. It enables content reuse, supports generation of new material and content exchange among students and encourages new pedagogical approaches allowing the inclusion of students with disabilities.

Keywords: Fab Lab, augmented reality, digital fabrication, universal design, disabilities.

1 INTRODUCTION

In Spain, the level of education of people with disabilities is comparatively lower than people without disabilities. A recent study (1), carried out in more than fifty universities, of the degree of inclusion of people with disabilities in the Spanish university system shows that the total number of students with disability in Spain is 17.634 people, which is 1.7% on the total of students. This percentage is even lower when talking of master, postgraduate or PhD students. Of the data provided in this sample, 51.8% were men and 48.2% were women, representing intellectual disability a 14.8% (men 9% and women 5.5%). Only about 5% of persons with disabilities have university studies, despite that the 2020 European strategy is talking of a 40%. These figures show that, despite the effort carried out by the Spanish universities in the last years to promote diversity and improve access of all persons with special needs in the university, it is still necessary to adopt measures to reduce early school drop-outs, promote access and guarantee higher education adapted to future needs.

A report on employment of people with disabilities published by the Spanish National Institute of Statistics (INE) in 2017, (2) indicates that the most significant feature of this group of students is their low labour participation: 35% activity rate compared to 78% for the people without disabilities. There was also a higher incidence of unemployment in the youngest population, as well as lower activity rates in those with intellectual disabilities (27.7%). The European Disability Strategy 2010-2020 (3) indicates that “quality employment ensures economic independence, promotes personal achievement and offers the best protection against poverty". To achieve the growth goals that the European Union has proposed, it is necessary that a greater number of people with disabilities exercise a quality and remunerated work activity in the ordinary labour market.

Moreover, the *Convention on the Rights of Persons with Disabilities* (4) declares that "states will ensure an inclusive education system at all levels, including higher education, to fully develop the human potential and the sense of dignity and self-esteem and reinforce respect for human rights,

fundamental freedoms and human diversity; as well as to develop to the maximum the personality, talents and creativity of people with disabilities, their mental and physical aptitudes". This will make it possible for people with disabilities to participate effectively in a diverse society, capable of developing the maximum potential of each person, and improving the expectations of achieving quality employment, which allows independence and freedom in decision-making of people with disabilities.

Researches show that the training of people with intellectual disabilities in the university environment, with a degree issued by the University, positively affects their employment in different business sectors and involves a mutual growth for students with and without disabilities. Gomes-Machado, Dos Santos, Schoen and Chiari (5) reported that the vocational training on people with intellectual disabilities contributes to their global development, favouring their professional inclusion and as a result, sustenance, autonomy, and a decrease in the need for assistance and support. Kleinert, Jones, Sheppard-Jones, Harp and Harrison (6) demonstrated how young people with intellectual disabilities are pursuing career goals and learning important life skills through participating in college courses, working with mentors and coaches and experiencing supported employment opportunities. Martín, Gasset and Gálvez (7) analyse the impact that the inclusion of young people with intellectual disabilities has generated in the university environment, highlighting the convenience of their inclusion in the college courses in order to build a better University.

However, according to Amor Pan (8), the training of people with disabilities developed under the protection of educational faculties do not address yet a specialized higher education, that would also contribute to this group to be better prepared, to integrate in the workplace and to promote their personal and social development. In this respect Harrison (9) suggested that best practice guidelines are needed with respect to university students with disabilities, and specialized programs may be required to address success and retention at the postsecondary level. Rodríguez-Martín and Álvarez-Arregi (10) demonstrate that access to higher education among students with disabilities must be promoted by making curriculum adaptations, training professors, improving accessibility and involving all the university community. Finally, Omaña and Alzolar (11) study reveals lack of teachers' information on disability and inadequate use of inclusion strategies at the university level, underlining the need of improving programs and teachers' training through a virtual space, oriented to the use of pedagogical strategies adapted to disable people.

2 OBJECTIVES

In this context, Fab Lab Madrid CEU, the digital fabrication laboratory based at CEU University is working to be permeable to this environment, promoting an inclusive education that contributes to the construction of a cohesive and respectful society that follows the principle of equal opportunities and non-discrimination. The premise for our work is to provide disabled students with new technologies to be competitive in the job market as well as to have access to the same opportunities as other students. To achieve this main objective, the following specific objectives have been established. First of all, providing university training through quality programs adapted to the demands of the labour market. Secondly, providing students with the necessary skills to improve their autonomy, their training academic and their job preparation, and thus increase their chances of employment. Thirdly, promoting inclusive initiatives within the university community, that provides a comprehensive and personalized training for young people with intellectual disabilities. And finally, contributing to the development of an integral educational model for people with intellectual disability, which will allow students to be trained to the maximum of their talent and of their abilities, and with the highest levels of social and labour insertion.

To that end, during the last years, some initiatives have been carried out at the Fab Lab oriented to promote the access of people with disabilities or special needs to our facilities, thanks to educational programs that promote their training and integration into activities at the university level. (12) Furthermore, at present, we participate in the Advance Diploma on Universal Design, a university program specifically designed for young people with intellectual disability to provide quality and innovative university training and a new qualification that help to improve their autonomy, their academic learning and their work preparation, in a context in which the legal framework and a growing social awareness increase the demand for accessibility and design solutions for all.

The program alternates the specialized theoretical-practical contents with transversal contents, as well as with the development of labour practices in real environments. The syllabus is structure in three modules: on the first one, accessibility in the physical environment, students learn to know the physical environment and understand plans and drawings, identifying different elements of signalling

and their characteristics according to regulations, On the second one, adaptation of texts, students learn resources to adapt texts and information and validate them, so that they are understandable following the principles of easy reading. And finally, on the third module, accessibility in digital environments, they learn about universal design applied to the web, social networks and human-machine interfaces and applications.

In this context, the digital fabrication laboratory will offer students access to new tools, as augmented reality and digital fabrication technologies that will allow them to improve their skills and social integration. Augmented reality can be viewed as an assistive technology, due to its potential to minimize the effects of a disability and provide an alternative means to accomplish a particular task. Digital fabrication, on the other hand, places an emphasis on the social aspects and benefits on students with disabilities are proved. Fab Lab users build confidence and engage with other people while developing technical skills. The combination of both technologies will promote social engagement while increase learner quality experiences.

3 METHODOLOGY

This paper describes a case study carried out at Fab Lab Madrid CEU that targets the use of augmented reality and digital fabrication as support technologies for students with disabilities to teach universal design in the college classroom. Participants include fifteen students between eighteen and thirty years with intellectual disabilities, enrolled in the National Youth Guarantee System. They have a degree of intellectual disability equal to or greater than 33%. All students have adequate and adjusted social and behavioral skills for inclusion in a normalized training environment. They are also motivated to receive specialized training in Universal Design and to perform a specific profession in this field. Students come from the Fundación Juan XXIII Roncalli, a reference foundation in the Community of Madrid with more than fifty years of experience in the development of training and employment programs for people with intellectual disabilities.

The case study will show the impact of the combination of augmented reality and digital fabrication technologies, as assistive tools for university students with disabilities. It will also show the benefits of the NEWTON Project platform, an innovative tool that allow students remote access to digital fabrication machines, enabling content reuse, supporting generation of new material and content exchange among students and encouraging new pedagogical approaches that allows the inclusion of students with disabilities. To that end, an educational program has been designed at Fab Lab Madrid CEU, structured in three activities: on the first one students were requested to design merchandising items using a software called Rhinoceros; the second activity focused on the use of 3D printers thanks to augmented reality technologies and finally, the third one involved the use of a Cloud Hub application designed for the NEWTON Project to use remotely the Fab Lab's 3D printers, allowing students to fabricate the products previously designed.

The first activity of the program involved the design of merchandising items for Fundación Juan XXIII Roncalli, in order to improve research and practice in Universal Design (UD), a term commonly used to describe goods and services that are usable both by persons with a disability and by typical users. (13) Although within product design, there have been significant efforts to develop specific guidelines and diverse research teams have designed product assessment methods extending the needs of UD to modern product design processes, (14) our initiative tries to go further and put these universal design methods into practice, counting on disabled students who participate in the design and manufacture of products. Students focused on the design of small gifts (keychains) that includes the logo of the Fundación Juan XXIII Roncalli, according to the precepts of universal design that are related to promote easy user hand manipulation of products designed for low physical effort. Prototypes included suggestions for shapes that allow someone with a sight limitation to locate the correct key and to read the logo of the foundation, which was engraved on the keychain.

In order to design the products, students were trained on the use of an open source software called Rhinoceros, through which students learn from scratch about the interface, the properties editor to view and modify objects, the report view to access the warnings and errors and the workbench selector to help selecting any command. Once students learn the fundamentals, they are requested to design some merchandising items according to Universal Design methods. They had to learn how to visualize 3D designs from different views and to create primitive objects, transforming them through Boolean operations to get the final shape. After that, students learned how to export the stereolitographic files of the 3D design to work in Ultimaker Cura, a 3D printer slicer application, in order to prepare the files to be 3D printed.

During the second activity, students learned how to use 3D printers to fabricate prototypes of the previously designed items. To that end, augmented reality was used as an assistive tool, due to its potential to minimize the effects of a disability among students and to provide a deeper understanding on the 3D printer procedures. It is worth to mention that students did not have any experience in the use of 3D printers. Moreover, they did not even know how a 3D printer works, as well as their components or materials needed. Therefore, it was absolutely necessary that students had the opportunity to see the machines in operation and interact with them for a clearer and more precise understanding of the workflow in a Fab Lab. In order to bring to Fundación Juan XXIII Roncalli students access to Fab Lab machines, two applications were used as new mediums for immersive learning, the *School Fab Lab* app and the *SFL AR* app, both created by Nader Shaterian and Simone Amber, founders of Fab Lab Connect.

Fab Lab Connect is a platform that brings resources to technology innovators from the digital Fab Lab community to scale up their solutions for social change. It is part of a movement initiated at the Massachusetts Institute of Technology (MIT) to address global issues and locally fabricate solutions. Both apps, offered access to learning for students who never have had access to Fab Lab machines, so they could experience technologies in a virtual way. Students experimented with placing 3D printer machines in the classroom and saw them function in a customized space. Thanks to it, it was possible to bring realistically scaled Fab Lab machines into a conventional classroom, set multiple machines in the space to design and create a virtual Fab Lab layout and finally, operate 3D printers in augmented reality to learn about the digital fabrication process and capabilities of each machine.

Figure 1. Students designing and using SFL AR app to operate 3D printers in augmented reality.

The third activity involved the use of a Cloud Hub application designed for the NEWTON Project to use remotely digital fabrication machines (3D printers), allowing students to fabricate the products previously designed. Fab Labs (digital fabrication laboratories) are considered as small workshops (15) equipped with a set of computer-controlled tools —3D printers, laser and vinyl cutters, milling machines and an electronics laboratory— that endorse a new learning paradigm, favouring the use of technology as a building material to promote innovative educational approaches. (16) The Cloud Hub application was developed at CEU University to implement the concept of Fabrication as a Service (17). More specifically, it is a real-time distributed hardware/software infrastructure that provides a software abstraction layer to the digital fabrication equipment and exposes it over the internet as a web service. The platform allows remote access to digital fabrication facilities. Thanks to the app, students learned how to send remotely 3D design files to be 3D printed at the Fab Lab facilities.

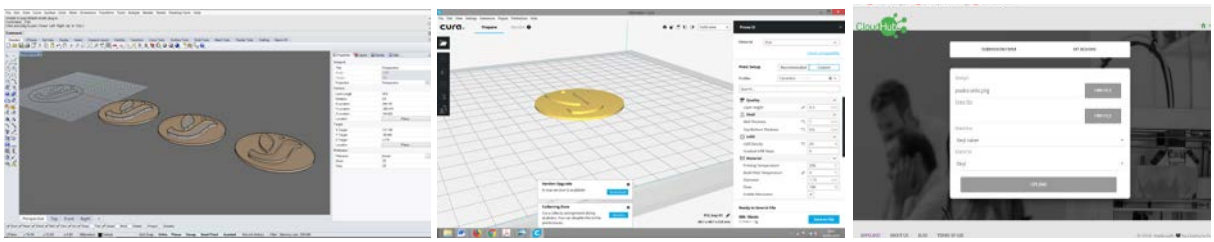

Figure 2. Designing with Rhinoceros, slicing with Ultimaker Cura and 3D printing with Cloud Hub app.

4 RESULTS

All participants on the case study (students and instructors) were invited to participate in interviews along with classroom observation. The core of the evaluation procedure employed was developed by the NEWTON project's Pedagogical Assessment Committee (PAC) (18) that provided guidelines for various assessments. Students were asked about their, gender, age, feeling about university studies and the use of technology. After that they were asked about their perception toward the program followed during the case study and their motivation while learning before and after the course. Finally, they were also asked about the usability of the Cloud Hub application for getting access to the Fab Lab facilities, as well as the use of augmented reality technologies. Besides, instructors carried out learner observational assessment after the course ended.

After collecting all data, the following results were found. Regarding their motivation in relation to university courses the answers ranged between "Very interested" (60% of students) and "Extremely interested" (40%). When asked about their interest in Fab Lab technologies, most students answered they felt very interested (80%) while 20% were "Somewhat interested". Related to augmented reality technologies, all students were highly engaged on the activities and said they were "Extremely interested" (80%) and "Very interested" (20%). One of the students was amazed by the opportunity to see "in virtual" as she stated and the possibility to "volunteer to virtually interact with Fab Lab machines". Finally, in relation with the Cloud Hub application, all students seemed to manage with the app, but just 30% of students stated to be "Extremely interested" and 70% was just "Interested".

After the analysis of the data collected through observation and also, the review of the designs and products fabricated by students, the following results were found. Firstly, it was proved that thanks to the combination of augmented reality and digital fabrication technologies, as assistive tools during the program, it was possible for students to design and remotely fabricate small prototypes of merchandising items following the rules of the Universal Design. Augmented reality was a helpful technology, in order to understand how to monitor 3D printers to non-trained students, reaching good results in a short period of time. It also helped in social interaction among students. Digital fabrication technologies helped participants to build confidence and engage with other people while developing technical skills to be competitive in the job market. Although this is an on-going program, it seems that the first results are promising and promote inclusive initiatives within the university community, contributing to the development of an integral educational model for people with intellectual disability, which could allow students to be trained to the maximum of their talent and of their abilities, and with the highest levels of social and labour insertion.

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