Opening Up Higher Education: An E-learning Program on Service-Learning for University Students

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Abstract. Higher education in Europe has been slowly implementing service-learning courses at the university in the last years. It allows students to take part in a community project as part of their course, providing a progressive learning experience while meeting societal needs. Madrid-based CEU University has been implementing service-learning elective courses on-site for the last five years through educational programs carried out in Fab Lab Madrid CEU, the digital fabrication laboratory based at the university. Thanks to it, students use digital fabrication technologies to design and make low-cost devices in cooperation with communities in need. As in the last two years, students have been increasingly taking their elective courses on-line; the number of students demanding e-service-learning courses has increased. To meet this demand, we have started to design an e-service-learning program, providing students remote access to Fab Lab technologies through the NEWTON Project platform and studying the outcomes of such effort.

Keywords: E-learning · Service-Learning · Higher education · Digital fabrication

1 Introduction

With the rapid growth and development of the information and communication technologies, e-learning has seen a fast evolution over the past decade. Being a viable alternative to traditional in-class learning, as well as a cost-effective training solution even in difficult economic circumstances, e-learning is increasingly adopted by educational, corporate and governmental worlds as an important component of information dissemination. The global e-learning market was accounted for $165.21 billion in 2015 and is expected to reach $275.10 billion by 2022, growing at a compound annual growth rate estimated at around of 7.5%. Several world regions appear to have significantly higher growth rates such as Asia at 17.3%, followed by Eastern Europe, Africa, and Latin America at 16.9%, 15.2%, and 14.6%, respectively.

The exponential growth of the e-learning market is making that both, private and public educational sectors, acknowledge the possibilities of novel technologies enhanced learning. These advances offer the chance to extend the learning experience to educational settings outside traditional classrooms and laboratories. Furthermore, these technologies

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can encourage research skills and interactive learning while considering students' individual learning styles. Most of higher education authorities believe that personalized, adaptive learning could make a positive impact in education. Preliminary research results have shown a link between a reduction in drop-out rates and utilizing e-learning software in education [1].

These technologies are not aimed at replacing teachers in the classrooms, but to empower them to teach at a deeper level, instead of merely trying to get through the curriculum. Several studies look at the benefits of integrating technologies in the learning process, e.g. improvement in attitudes of both, teachers and students and increase in skills [2]. Furthermore, technologies like adaptive intelligent systems can help bridge the gap between low and high achievers [3].

E-service-learning (electronic service-learning) combines on-line learning and service-learning, an educational approach that integrates learning objectives with community service in order to provide a pragmatic, progressive learning experience while meeting societal needs. The combination of both, e-learning and service-learning, enables the delivery of the instruction and the service to occur partially or fully online. E-service-learning allows students anywhere, regardless of geography, physical constraints or other access limitations, to experience service-learning. It reciprocally also equips online learning with a powerful tool for engaging students [4].

In spite of the rapid growth in e-learning in all its forms and the reality that an increasing number of students are pursuing their education online, service-learning has kept pace without exposure to the benefits of the innovative technology enhanced learning methods and tools. Goertzen and Greenleaf [5] highlighted diverse examples of e-service-learning courses representing various levels and academic disciplines. It is also worth to mention Lih-Juan, Hong-Yen and Tze-Han [6] initiatives that integrates service learning into the curriculum in learning projects where college students e-tutoring children in remote areas. However, despite all, nowadays, yet few university students are exposed to service-learning in their online coursework. According to Waldner, McGorry and Widener [7], service-learning must go online to remain relevant. E-service-learning holds massive potential to transform both service-learning and online learning by freeing service-learning from geographical constraints and by equipping online learning with a powerful tool to promote engage.

2 Objectives

The Department of Architecture and Design at Madrid-based CEU University has been implementing service-learning elective courses on-site for the last five years through educational programs carried out in Fab Lab Madrid CEU, the digital fabrication laboratory based at the university [8]. Thanks to it, students use digital fabrication technologies to design and make low-cost devices in cooperation with communities in need [9]. As in the last two years, students have been increasingly taking their elective courses on-line; people demanding e-service-learning courses has also increased. To meet this demand, we have started to design an e-service-learning program.

The program provides remote access to Fab Lab technologies through an innovative platform that allows university students to acquire skills on digital fabrication.

It has been created as part of a large European Union Project called NEWTON. It allows students to design and fabricate low-cost devices to be provided to communities in need, thanks to courses that run between on-site activities and remote access to digital fabrication facilities.

The main objective of the training program has been to raise awareness of the pedagogical potential of the combination of e-learning and service-learning at the university level, freeing service-learning from geographical constraints and providing college students remote access to digital fabrication tools to work with communities in need. To achieve this main objective, the following specific objectives were established. First of all, providing on-line university training on digital fabrication through quality programs thanks to the NEWTON Project platform. Secondly, design and fabricate products and services to solve a need of a community based on technology. Thirdly, reinforcing the social awareness of university students promoting initiatives that involve the cooperation among the university with partners such as communities, NGOs and foundations, and finally, contributing to the development of an integral educational model, which will allow students and faculty to experience the benefits of e-service-learning.

3 Methodologies

In order to achieve the previously stated objectives, a variety of activities has been designed, as e-learning classes on theoretical and practical foundations of service-learning, as well as collaboration with NGOs working in direct cooperation with communities that need support through both, on-site and on-line fieldwork. It also involves an on-line training course on the use of digital fabrication technologies through the NEWTON platform, which includes open access to our pedagogical materials and remote access to Fab Lab machines and designs. This innovative platform is allowing us to move from on-site service-learning courses to on-line classes.

The present paper describes a case study that focuses on the practical outcomes of the use of the NEWTON Project platform to allow university students to acquire skills on digital fabrication technologies and remote access to Fab Lab machines, in order to design and fabricate low-cost devices in cooperation with communities in need. Specifically, we focus on an initiative that involved fifteen students on the design and fabrication of a low-cost incubator for the Makeni Public Hospital (Sierra Leone).

The purpose of the workshop is to compare two methods of fabricating the above-mentioned device: on the one hand, the usual procedures we have been following in previous workshops, in which we use digital fabrication machines on-site and on the other hand, testing the NEWTON Project platform to remotely monitoring Fab Lab machines. The scope of this study is to evaluate the usability of the NEWTON platform, in order to assess whether it is worthwhile to implement its use as an educational tool in the e-learning program that we are trying to implement.

The workshop is organized in two activities: the first one is related to design procedures and focuses on the implementation of an open-source low-cost incubator design in a computer based software; and the second target the digital fabrication of the previous designs, both, on site and remotely through the NEWTON platform.

Design Process. The first activity focused on design procedures. Based on open-source previous designs of a low-cost newborn incubator, students were requested to implement the design in computer software according to the requirements of the Public Hospital of Makeni, in Sierra Leona. The previous design of the incubator was designed by Alejandro Escario, a former student of Fab Lab Madrid CEU, who is still collaborating on service-learning programs carried out at the laboratory. His goal was designing and making an affordable incubator for hospitals in developing countries easily replicable and repairable. In order to do so, designs, sources and documents were uploaded on a public repository under an open source and open hardware license [10] to allow free access to them for those who are interested in collaborating on the project, improving the design or fabricating incubators for communities in need.

In terms of design, the structure of the incubator is robust, but it is also easy to build and repair without having much knowledge about design or electronics. Inexpensive materials such as wood, plastic as well as recycled components were used to reduce the cost. The incubator's bed could be slightly tilted manually and the isolation of the incubator is assured through an easy removable plastic surface, so that the interior could be quickly and easily accessible to medical staff. It was made using 1.75 cm plywood. A press fit method was used to fasten parts, as it is achieved by friction after the parts are pushed together, rather than by any other means of fastening, assuring a quick and easy assembly (Fig. 1).

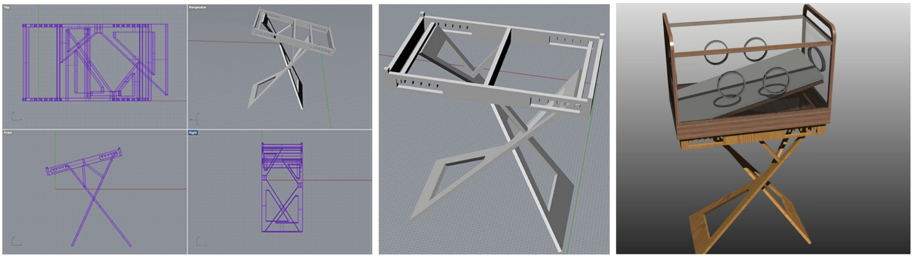


Fig. 1. Original design of the low-cost incubator designed by Alejandro Escario in Rhinoceros.

The methodologies used during the design process combine Self Directed and Independent Learning with Project Based Learning (PBL), two innovative approaches that are possible in the e-learning environment that lead to new models of education as well as new teaching and learning methods.

3.1 Self-Directed and Independent Learning

Flipped Classroom involves creating online multimedia content that is used out-of-class in conjunction with in-class learning activities such as individual and collaborative problem solving, group-work and class discussion. From the published research [11], there is evidence that the Flipped Classroom pedagogy inadvertently follows a constructivist approach towards learning where a student constructs their own learning and promotes self-directed and independent learning outside-of-class. It flips Bloom's taxonomy [12] and entails other thinking activities (creating, evaluating, analyzing) in the classroom. The use of this pedagogy during the first phases of the design process allowed university students to get access to pedagogical content related to the first activity. Students were requested to get access to design files and were trained on the use of a 3D design software called Rhinoceros that allowed them to visualize, modify and design new pieces that could improve the design of the incubator. After that, a Design Thinking approach is followed by the group of students to find out the best way to integrate the requirements of hospital's medical staff.

3.2 Problem-Based Learning

Problem-based learning (PBL) is another modern student-centered teaching method that uses real-world problems as the motivation of a self-directed learning process. Particular for PBL is that the problem comes before the knowledge needed for the problem. Typically, the learner applies new knowledge provided through teaching to solve a problem. This pedagogy requires learners to use the problem to direct them to research and learn the new knowledge needed. A number of educators have explored its potential by designing and delivering modules that make use of this teaching technique [13]. It supports the achievement of higher cognitive levels and develops life-long problem solving skills. Confronting students with the task of solving a design problem for a real client, make them to feel motivated. Receiving feedback from the users makes the final product the result of a collaborative effort in which users and designers propose improvements, taking product design to a higher level.

Digital Fabrication. After finishing the design improvements of the low-cost newborn incubator in Rhinoceros, the second activity targeted the digital fabrication of the previous designs first, using digital fabrication machines on-site and after that, remotely through the NEWTON platform.

3.3 Digital Fabrication Laboratories (Fab Labs)

Fab Labs are small-scale workshops with a set of flexible computer-controlled tools and machines such as 3D printers, 3D scanners, a mid-size laser cutter, CNC machines, a printed circuit board miller and some basic tools. Fab Lab environment is an inspiring and creative surrounding that provides students digital fabrication resources and allows educators to develop hands-on and collaborative teaching practices [14]. For their own intrinsic nature, they can be seen as laboratories to acknowledge and embrace different learning styles and where "students can concretize their ideas and projects with intense personal engagement" [15]. Fab Labs stimulate students to come up with new ideas and especially to fabricate prototypes. It is a perfect illustration of 'learning by doing', as all tools to bring a product to a realization are in reach.

The Fab Lab concept is gaining a worldwide interest and governments are starting to recognize the importance of digital fabrication technologies. Presently, there exists a worldwide network of more than 1.000 Fab Labs located in more than forty countries coordinated by the Fab Foundation. From community-based labs to advanced research centers in universities, Fab Labs are democratizing access to the tools for technical invention. This community is simultaneously a manufacturing network, a distributed technical education campus, and a distributed research laboratory working to digitize fabrication and inventing the next generation of personal fabrication.

As the scope of the case study is to compare digital fabrication using both, Fab Lab machines on-site and remotely through the NEWTON platform, students were requested to fabricate some pieces of the incubator's prototype using the first approach and the rest of the parts using the second. In the first one, students needed to create a dxf (drawing exchange file) starting from Rhinoceros, including all the pieces to be milled on a computer numerical control machine (CNC). After that, students used VCarve, a software solution for cutting parts on a CNC router. The software can import 2D designs providing a full set of drawing and editing tools.

VCarve toolpath options cover all routing operations such as profiling, pocketing, auto-inlays and drilling. Besides, each toolpath includes options to customize the settings and provide a high level of control for different types of operation. Thanks to it, students can easily introduce all needed parameters, such as the size of the material, the cutting depth, the type of profile's toolpath, the number of tabs, the size of the end mill and the type of cut according to the layout.

The work can be previewed to show how the parts will look when they are cut. After that, toolpaths are saved in the proper file format to drive the machine. Finally, students are also trained on the use of the machine on-site, which includes the placement of the material on the table, the way to place the mill on the router and the use of the software that monitor the CNC machine (Fig. 2).

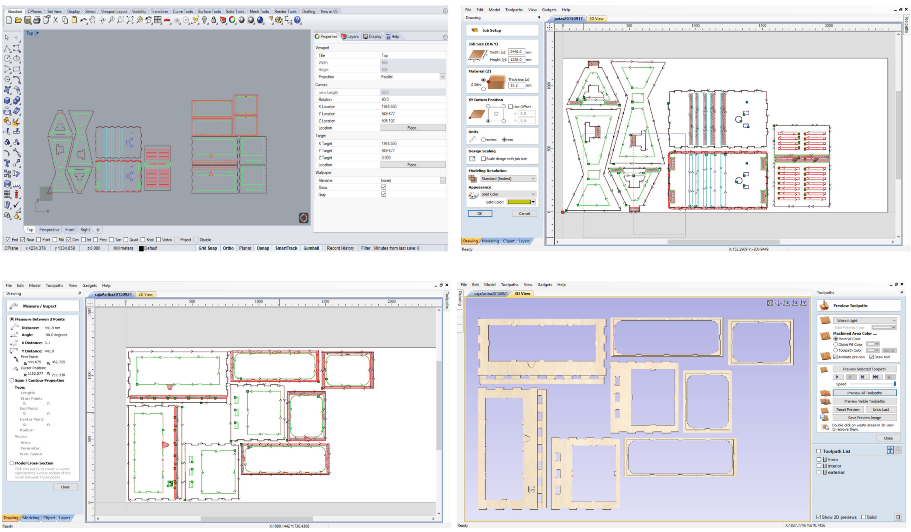


Fig. 2. Screenshots of the incubator designed in Rhinoceros (top left), a dxf file imported in VCarve (top right), toolpaths in VCarve (bottom left) and a preview in VCarve of the work to be milled in plywood (bottom right).

3.4 Remote Access to Fab Lab Facilities Through the NEWTON Platform

The integration of the Fab Lab workflow as part of the e-service learning program is possible thanks to the Cloud Hub application designed for the NEWTON Project [16]. NEWTON is a large European Union project focused on the integration of new solutions for technology-enhanced learning that enables learning content use and supports the generation of new material and content exchange among students to increase learner quality of experience for all. This tool creates new opportunities by providing an integrated approach where students can use remotely Fab Lab machines.

In order to do that, students started creating a portable network graphic (png) file starting from the Rhinoceros file that includes all the incubator's pieces to be milled. After that, students needed to get access to the platform, through which students got a quick and easy access to Fab Lab machines without having any knowledge on how to use the software associated to each machine. Using the application, students selected the Fab Lab machine to be used (a CNC machine), the material to be milled (plywood) and the size of the end mill.

After students sent the png file, it is received on a Raspberry Pi connected to the CNC machine at the Fab Lab. Then, a lab technician is in charge of preparing the material on the Shopbot and finish the process. Parameters needed to fabricate the pieces are assigned automatically according to the information selected by students before sending the file. After that, the file can be milled on the CNC (Fig. 3).

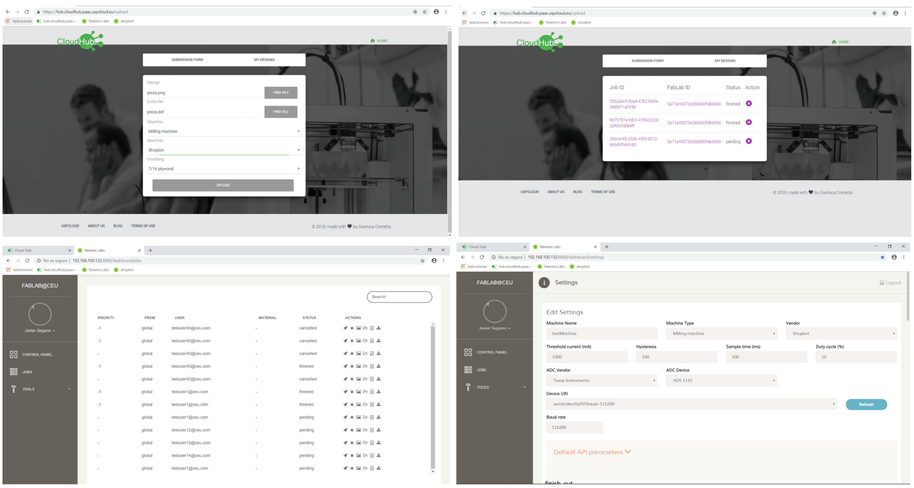


Fig. 3. Cloud Hub app student's interface (top) and Cloud Hub technician's interface (bottom).

Thanks to the NEWTON platform, students with no previous training in Digital Fabrication interested in participating in our e-service-learning program will be able to work on the implementation of the design of these medical devices to be manufactured in our Fab Lab. The Cloud hub app is responsible for transforming a simple png file exported from a 3D design program into a file suitable to be milled on a CNC machine. Students only select the machine to be used, the material and the type of end mill. The ease of use of the application will allow opening Fab Lab technologies to people with special needs or with some type of disability.

After the pieces were milled, the incubator was ready to be sent to the Public Hospital of Makeni in Sierra Leone. Both, the plywood's pieces and the electronic components were placed into a flat box that included some assembly instructions to be easily assembled by medical staff at the destination hospital.

During the last five years, our Fab Lab have been making and donating low-cost incubators through our service-learning programs to various maternities and hospitals on the African continent, such as Nikki's Maternity in Benin, thanks to Alaine Foundation; Magbenteh Hospital in Sierra Leone, thanks to the NGO Swis Sierra Leone Development Foundation; Pouponniere Orphanage in Senegal; St. Joseph Hospital in Ghana and Children's Center of Kakikoka in Benin, thanks to the NGO Solidarity Foundation with Benin.

In this case, the incubator was sent to the Public Hospital in Makeni, Sierra Leone, thanks to the cooperation with the University of Makeni. Clara Abella Dutrús, former student at CEU University, was responsible for the assembly and even organized a training course at Makeni's University, in Sierra Leone, to involve students of Public Health in the project. They are now in charge of collecting data related to the usability of the incubator that will allow testing the medical device (Fig. 4).

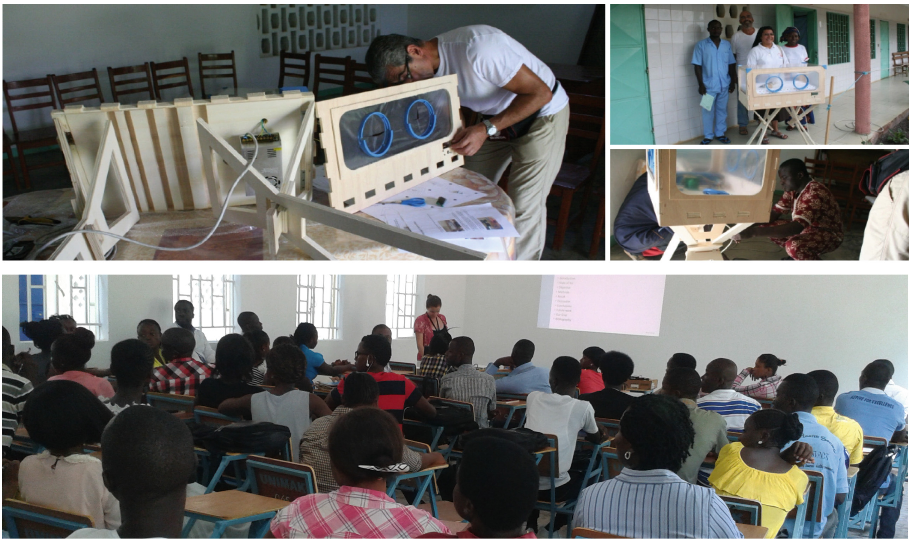


Fig. 4. Medical staff assembling a low-cost incubator in the destination hospital (top) training course for students of Public Health at the University of Makeni, Sierra Leone (bottom).

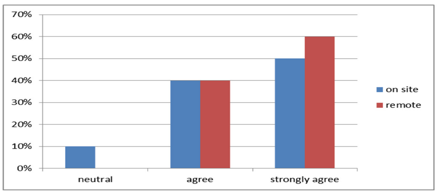
4 Results

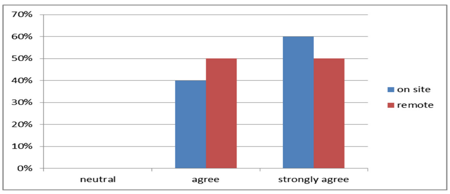
The core of the evaluation procedure employed in the case study was developed by the NEWTON project's Pedagogical Assessment Committee (PAC) [17] that provided templates and guidelines for various assessments including various questionnaires. Firstly, a Learner Demographic questionnaire was used to collect information about learners, such as gender, age or background. Secondly, a Learner Motivation questionnaire (pre and post activities) was used to assess learners perception toward service-learning and e-service-learning activities. Finally, a Learner Usability questionnaire was handed-out to assess learners feeling about the usability of Fab Lab machines on-site and remotely through the NEWTON Project platform. Besides, instructors carried out learner observational assessment during activities.

Results obtained after collecting data are discussed below. The Learner Demographic questionnaire revealed that 55% of university students involved on the case study were males and 45% were females. Participants' ages ranged from 19 to 23 years. On the other hand, 30% of students were studying a degree associated to cooperation while 70% of students combined service-learning activities with university studies related to diverse fields. The Learner Motivation questionnaire was used to assess learners perception toward service-learning and e-service-learning activities. When asked about their interest on service learning programs that run in our Fab Lab 80% of students answered that they were "Extremely interesting" while 20% of participants said "Very interesting". When asked about their possible interest into participating in an e-service-learning program, 70% of students answered they were "Extremely interested" while the rest of students said they were "Somewhat interested". The evaluation shows a greater interest in e-service-learning in those students who cannot devote all their time to service learning activities, as they have to combine volunteering with university studies.

Regarding the Learner Usability questionnaire students had to answer three types of questions referred to usefulness, ease of use and ease of learning. In relation to usability and usefulness, students were asked if Fab Lab technologies (on-site and remote) help them to be more effective. As it is shown in the tables below, similar answers were given from students when asked about the effectiveness and usefulness of both, on-site Fab Lab tools and remote access to them through the NEWTON platform. However, the percentages slightly vary when participants are asked if this technologies save them time. 30% of students "Agree" and 30% of students "Strongly agree" when asked about on-site Fab Lab technologies, while 40% "Agree" and 60% "Strongly agree" when asked about their use through the NEWTON platform (Table 1).

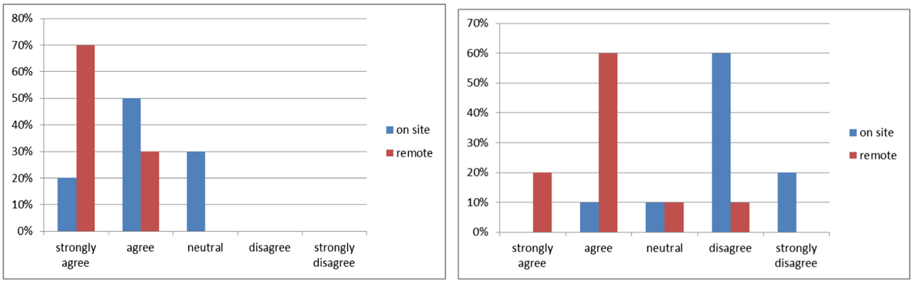
Table 1. Effectiveness (left) and usefulness (right) of Fab Lab technologies used on-site and remotely through the NEWTON Project platform.





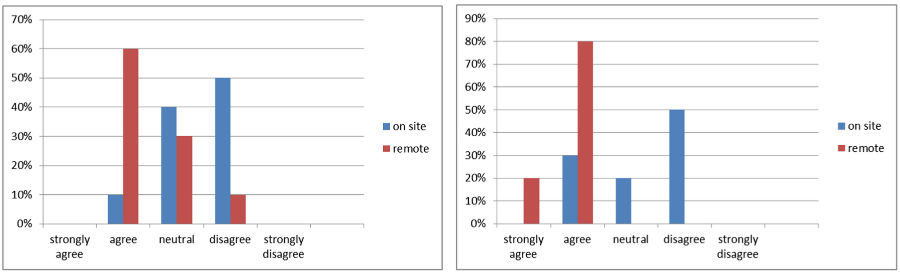
When asked about the ease of use, it is worth to mention that 70% of students "Strongly agree" on the ease of use of Fab Lab machines remotely versus 20% of students that answered the same to this question related to the use of machines on-site. Percentages vary considerably when students were asked about machine's use without instructions on-site and remotely. 60% "Strongly agree" to that questions when asked about the NEWTON platform (Table 2).

Table 2. Ease of use (left) and use without instructions (right) of Fab Lab technologies used on-site and remotely through the NEWTON Project platform.



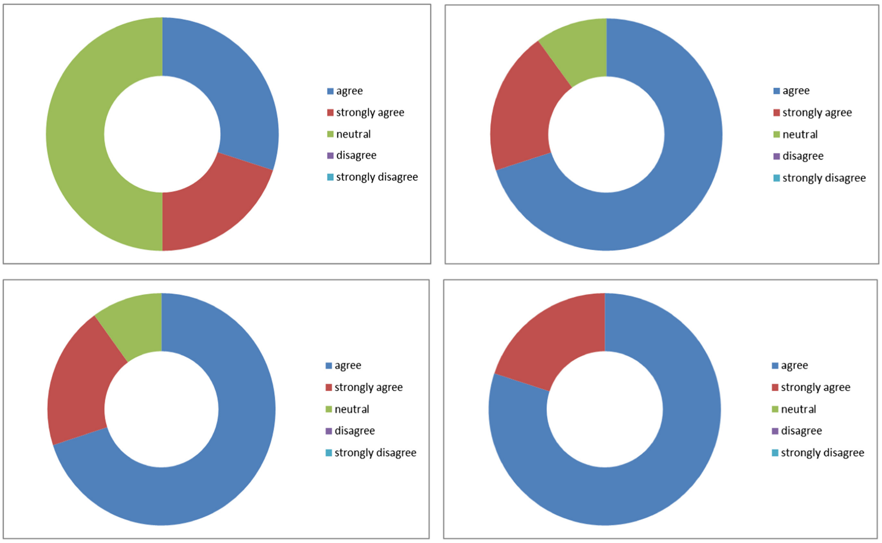
On the other hand percentages of students that said that the technologies requires the less fewest steps possible reach to a 60% when asked about the NEWTON platform. Finally, when asked about the safety in use, percentages reach a 80% of students when refer to the remote use of Fab Lab machines (Table 3).

Table 3. Feeling about steps requirements (left) and ease of remembering steps (right) of Fab Lab technologies used on-site and remotely through the NEWTON Project platform.



Regarding questions about ease of learning, 70% of students "Agree" on the ease of learning of the NEWTON platform, while just 30% of students "Agree" when referring to Fab Lab machines on-site. Similar percentages were obtained when asking if students could easily remember how to use it. 80% of students "Agree" to this statement when referring to the remote access to Fab Labs and just 20% of students agree when alluding the use of the machines on-site (Table 4).

Table 4. Ease of learning. Answers to the question about learning quickly Fab Lab technologies on-site (top left) or using the NEWTON platform (top right). Answers to the question 'I can easily remember how to use it' Fab Lab technologies on-site (bottom left) or using the NEWTON platform (bottom right)



5 Conclusions

Results reveal that most of the participants of service-learning programs that run at the Fab Lab are also interested in e-service-learning activities. The evaluation shows greater interest in e-service-learning in those students who cannot devote all their time to service learning activities, as they have to combine volunteering with university studies. Regarding the comparison between the conventional use of Fab Lab technologies in the field of service-learning and the use of the new NEWTON platform that allow remote access to digital fabrication technologies, students seems to agree on the idea that both methods help them to be more effective and save them time. However, when asked about the ease of use, the need of instructions to use Fab Lab technologies, the safety of their use and the ease of learning, a high percentage of students bet on the use of the NEWTON Project platform.

After the case study, our e-service-learning program will include some activities that allow students to use the NEWTON Project platform to promote active learning and new educational approaches that improve the service-learning programs, allowing students to free service-learning from geographical constraints and provide university students remote access to digital fabrication tools to work with communities in need. Work is ongoing but we expect that this initiative contribute to the development of an e-service-learning program, which will allow students and faculty to experience the benefits of working collaboratively with communities in need.

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