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Training Future ICT Engineers in the Field of Accessibility and Usability: A Methodological Experience

MARÍA LUISA PERTEGAL-FELICES[1], DIEGO MARCOS-JORQUERA[2], ANTONIO JIMENO-MORENILLA[2], RAQUEL GILAR-CORBI[1], AND HIGINIO MORA[2]

[1]Department of Developmental Psychology and Didactics, University of Alicante, 03690 San Vicente del Raspeig, Spain
[2]Department of Computer Technology, University of Alicante, 03690 San Vicente del Raspeig, Spain

Corresponding author: Diego Marcos-Jorquera (dmarcos@dtic.ua.es)

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ABSTRACT Nowadays, digital culture affects all levels of society. However, differences exist between individuals, commonly named as the ''digital divide,'' which impedes the equal access to the benefits of new technologies. The Usability and Accessibility (UA) module is a core, first-semester module during the first year of the Multimedia Engineering degree at the University of Alicante. The UA module's main objective is to provide students with the necessary concepts and tools to design and develop products with usability and accessibility features, thus achieving end products that are more usable and accessible, regardless of the end users' status, ability or situation. This paper presents a new learning methodology aimed at making students become everyday users of their own digital products. Daily use of these products improves the UA learning process, since students can appreciate their accessibility and usability in everyday life conditions for a better understanding of how their own design decisions affect potential users. A non-equivalent control group design with pre- and post-test control groups was used to test the research hypothesis. The results of this study showed a significant improvement in their academic performance compared to the control group.

INDEX TERMS ICT engineers' training, accessibility, digital divide, usability divide.

I. INTRODUCTION

The World Summit on the Information Society (WSIS) created one of the broadest and highest platforms in the area of communications in the history of the United Nations [1]. This multi-year event included two intergovernmental summits: Geneva 2003 and Tunis 2005. The concluding report confirmed that information and communications technologies (ICTs) have immense impact on practically every aspect of our lives [2]. Technology provides millions of people throughout the world with unprecedented opportunities to reach higher development levels. It can reduce many obstacles, notably time and distance, and promote dialogue between people, nations and civilisations. Furthermore, it is an effective tool for increasing productivity, generating economic growth, creating employment and boosting employability, as well as improving the quality of life for all. However, ICTs are not equally distributed among countries (developed and developing), or within societies, creating a digital divide between citizens.

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A. DIGITAL DIVIDE

''Digital divide'' is a concept that came from President Clinton's mandate. This concept intended to express the differences between people in the United States who had access to new technologies and those who did not [3], [4]. The Digital Divide was related to the efforts that the government had to make to ensure the necessary investments to help people access new technologies [5].

Although the concept originated in individuals being able to access technology, it does have several dimensions. The ''global divide'' determines the access differences between industrialised and developing countries. The ''social divide'' refers to accessibility related to socio-economic differences between people that have access to the Internet and those who do not. Lastly, the ''democratic divide'' exists among those who are online and marks the differences in how they use ICTs for engaging, mobilising and participating in public life [3]. This last dimension has a much wider scope and in addition to Internet access, refers to all tools related to ICTs (mobile telephones, network technologies, telecommunications, personal digital assistants [PDAs] and other devices). The ''democratic divide'' therefore helps us evaluate and understand the differences in technology access among groups, people and geographical areas, their normalised use and ability to enjoy the advantages associated with them [6]. The dimension ''digital literacy'' appears in the area of education, which refers to the basic skills needed to face digital life on a critical level (as an information discriminator/selector) or on a security level when using ICTs [7]. This article focuses on the problems associated with the ''online'' group who are affected by the dimensions ''democratic divide'' and ''digital literacy.'' Hereinafter, the concept ''Digital Divide'' shall be understood to be referring to these areas.

According to the Organisation for Economic Cooperation and Development (OECD), the term ''digital divide'' is defined in terms of access to ICTs, the Internet and the skills needed to use these technologies. The OECD defines technology as a social process and considers that ICT skills are as important as access to technology itself in bridging the digital divide [8]. To this end, although people have access to technology, the difference lies in how they use it and their user skills, which leads to the definition of the ''techno-rich'' and ''techno-poor'' in accordance with the quality of technology use [9]. This same concept is introduced by Van Seters, de Gaay Fortman, and de Ruijter [10] when they confirm that poverty is not only measured by economic or social terms. The world is now also divided by those who have mastered new ICT skills and those who have not.

Although governments have made several efforts to bridge this gap, the subject is still a concern for many. The OECD [11] developed a project that evaluated the work-related skills of people aged between 16 and 65 years of age, examining the ICT skills of 200,000 people in 33 countries. The results showed that an important percentage of adults were lacking basic ICT skills, demonstrating that they were not able to solve problems in technology-rich environments. However, using ICTs in the workplace is not the only limitation that the ''digitally illiterate'' face. Digital illiteracy also affects other dimensions such as identity and security.

A study by Best, Manktelow and Taylor [12] reports that the use of online technologies provides benefits related to self-esteem, perceived social support, increased social capital, safe identity experimentation and increased opportunity for self-disclosure. However, the same report states that little knowledge of how to use these environments is also conducive to damaging aspects such as increased exposure to harm, social isolation, depression and cyber-bullying.

Information security is another of the subjects that most concerns public and private entities. The divide is often not associated with a lack of knowledge but with a disparity between the objectives of those who design ICTs and those who use them. Albrechtsen and Hovden [13] proved that Security system managers and users were not in tune with one another, in the sense that both had different points of view concerning the same problem. The study revealed that the differing interpretations were due to the Security managers basing their practical method on unrealistic assumptions about users, which were therefore poorly aligned with the users' daily work dynamics.

B. HOW TO BRIDGE THE DIVIDE

Since 2005, the United Nations (UN) has established mechanisms and recommendations that prompt governments to set specific policies aimed at reducing technological inequality [14]. This institution agreed to create ''an information society for all'' as one of its fundamental principles to guarantee that the opportunities that ICTs offer are beneficial to everyone. To ensure that this principle is achieved, all interested parties must collaborate in different aspects, including developing and broadening ICT applications and promoting ability, confidence and security in ICT usage. The UN's plan of action was centred on developing and promoting ICTs in areas such as infrastructure, content and applications. In line with the UN's recommendations, governments are adopting measures. Technological infrastructure can be one of the strengths in a country, while another could be changes to teaching practices to make citizens digitally literate [15]. To this end, policies are being developed, which aim to promote access to technology and its use, seeking digital literacy, the rational use of technology and its impact on daily life, security, etc. New technologies are being taken into account in curricula at all levels of education, which include ''digital competence'' as a key skill [16]–[18].

The academic world has also sought to make these governmental policies more effective. Several studies provide recommendations on how to bridge the digital divide. For van Deursen and van Dijk [19], one of the main issues lies in the lack of skills, but this problem increases when governments assume that citizens are more skilful than they actually are. The Dutch government's expectations that citizens are capable of completing the digital tasks requested —examined in the paper— were not justified. The authors recommend two types of policy to change this situation: recommendations to improve government websites and to improve citizens' qualification levels. Van Dijk and Hacker [20] confirm that the digital divide is related to different categories of income, employment, education, age and ethnicity. They showed that the differential access of skills and usage is likely to increase, projecting that the usage gap will grow. Furthermore, their studies reveal the surprising effect that age and gender have in comparison to education and relate the usage gap to evolution of the information and network society.

Once governments have adopted measures to provide the public with the physical tools needed to bridge the digital divide (computers, Internet access, etc.), then the public need to make effective use of them. The objective is to achieve a *digital citizenship*, which, according to Ribble [21] is reached when certain characteristics are acquired, such as understanding cultural, social and human issues and practising legal and ethical behaviour; advocating safe, legal and responsible use of information and technology; exhibiting positive attitude towards using technology that supports collaboration, learning and creativity; demonstrating personal responsibility for lifelong learning; and exhibiting leadership for digital citizenship [22]. The best way to obtain digital citizenship is through education. To ensure that students actively participate in this digital citizenship, their training must be directed toward digital access, digital commerce, digital communication, digital literacy, digital etiquette, digital law, digital rights and responsibilities, digital health and wellness and digital security [23], [24].

C. USABILITY DIVIDE

Although citizens eventually obtain good digital skills, a new divide can arise that prevents them from effectively accessing the benefits of ICTs. This new obstacle, called the ''usability divide'' [25] refers to the difficulties that citizens face to make use of technology and the degree of simplicity and effectiveness that technology creators provide their creations. Citizens must have minimum skills to be able to use the technology, but engineers must also be in tune with their potential users' needs to provide solutions that facilitate and maximise product usage. This paper will focus on the ICT engineer side.

Several studies demonstrate the difficulties that engineers can create with regard to ICT access. In addition to the aforementioned study by Albrechtsen and Hovden [13] on the lack of understanding between Security system managers and users, Shneiderman's paper [26] describes serious difficulties involved in creating a successful ecommerce business. For Shneiderman, it is not only about using low-cost hardware or broadband networks, emarket services are often too complex, unusable and even irrelevant for too many users. In this situation, design and usability are the key factors for success. The cause of these problems is often linked to designers making incorrect assumptions about users' knowledge and requirements. These false assumptions are related to the difficulty in understanding technical vocabulary and/or advanced concepts that are not well explained. Unfortunately, most designers are not aware of how destructive this could be for novice or even expert users [26].

What is usability for an ICT engineer? It is a broad concept that has several definitions. According to international standards [27], ''usability'' is the degree to which the software product is understood, learned, used and attractive to the user when used under specified conditions. For Nielsen [28], it refers to the user's experience when interacting with a website. Therefore, a ''usable'' product is one that can be clearly and simply understood by users.

One of the main barriers that engineers must overcome is being responsible for designing products that they may not necessarily use, i.e., they need to be able to predict what would be a good user interface. Engineers who design products without knowing the users' needs have to use their intuition to detect them [29], [30]. Designers are extremely different to most of their products' users, not only concerning irrelevant aspects such as what they like, but with other essential aspects, such as what they believe is easy to use. Trusting said personal preferences and intuitions is often misleading and the reason why product designs can be disastrous [31].

The terms usability and accessibility often cause confusion. The term accessibility refers to the universal access to information of all people, regardless of the circumstances and the devices used. For Hassan and Martin [32], accessibility is the highest possible number of users being able to access and use a web service or product, regardless of individuals' own limitations (abilities, knowledge, languages, experiences, etc.) or those derived from the usage context. However, for these authors, accessibility does not only involve the need to facilitate access, but the need to facilitate use. A design is accessible when it is usable for more people in more situations or usage contexts [33], making efficiently and satisfactorily carrying out and achieving tasks possible for all users [28]. For Henry [33], accessibility is a subset of usability; it should be understood as ''part of'' and a ''requirement for'' usability. Therefore, the distinction between usability and accessibility indicated by Henry may be considered difficult, and unnecessary in many cases.

Future ICT engineers learn about Usability as a Software Engineering concept at universities. To this end, it is mainly in these institutions where several experiments have been conducted to bridge the ''usability divide.'' In the academic environment, Nielsen's books [28], [31] are one of the basic references used by usability students. At Toronto University, Baecker, Booth, Jovicic, McGrenere and Moore [34] prepared three projects to make complex designs more accessible to novice users, including a text processor that gave users control over the interface's complexity. From the University of Graz (Austria), Holzinger [35] reviewed inspection methods designed to make detecting usability problems easier and other end-user-oriented test methods that provide feedback on the real use of applications. In other works, procedures based on the evaluation of Usability Engineering and User Experience are proposed, as in [36] where it is applied to the evaluation of scientific special interest internet services.

Although many contributions have been made on the concept of usability, there are very few studies aimed at changing the way that future ICT engineers perceive and practice usability. Øvad and Larsen [37] presented a study in which students had to sit a ''focused workshop'' where medical professionals informed the future developers of their daily work needs in order to make designing medical applications easier. However, this type of specific course limits the time students have for the rest of their studies.

D. OBJECTIVES AND HYPOTHESIS

The objective of this research is to check if a new practical methodology to teach usability and accessibility concepts can improve future ICT engineers' skills related to these concepts. This experiment was conducted with Usability and Accessibility students enrolling Multimedia Engineering at the University of Alicante (Spain). The research hypothesis is that making students everyday users of the products designed in class will improve their usability and accessibility skills. Thanks to this methodology, students will gain a better understanding of how their design decisions could affect the potential users of their applications.

The paper is organised as follows: The methodology section shows how the research was conducted and what the learning experience consists of. The results section evaluates the effect that the experience has had on the experimental student group compared to the control group. Lastly, the conclusion section discusses the most relevant contributions from this study.

II. METHOD

A. PARTICIPANTS

A new degree emerged in response to the growing demand for ICT specialists who are able to design new multimedia projects in the digital leisure and entertainment sector and content management sector for dissemination on information networks: Multimedia Engineering. This degree is placed between traditional engineering and computer engineering and its scope of work is specially aimed at the design and development of websites, web apps, mobile apps and video games.

This study was conducted at the University of Alicante, which has offered this degree since the 2010/2011 academic year. The degree has been widely accepted since it was introduced at the university, having filled all places each year. Furthermore, each year group has graduated with a high employment rate, which justifies the role played by these new professionals.

The ''Usability and Accessibility'' module is part of the Multimedia Engineering degree. Its objective is to analyse and create user interfaces with usability characteristics, which are easy-to-use, understandable and concise, as well as accessible, meaning that they can be used by a maximum number of users, regardless of their characteristics, access devices or context, especially focusing on users with any type of disability.

The following skills are developed during the Multimedia Engineering degree's Usability and Accessibility module:

- Developing, maintaining, administering and evaluating multimedia services and systems that satisfy all user requirements and act in a reliable and efficient way, complying with quality standards.
- Creating, designing and evaluating human-computer interfaces that guarantee accessibility and usability.
- Designing, producing and managing multilingual and multimodal systems of multimedia content with the objective of guaranteeing their internationalisation, localisation, accessibility and usability.

The UA instructional model is based on the Task-centered Instructional strategy following the principles proposed by Merrill [38]. This type of strategy, particularly suitable for engineering education, involves the student in four distinct phases of learning: (1) activation of prior experience, (2) demonstration of skills, (3) application of skills, and (4) integration or these skills into real world activities.

The study was conducted during the first term of the 2017/2018 academic year. The 70 students enrolled on the Usability and Accessibility module participated in the study. The course lasted 15 weeks with four hours of face-to-face classes per week. Figure 1 shows the milestones associated with the course programme.

Three projects are carried out during the module. For the first two projects (P1 and P2), students are asked to design human-computer interfaces with which users strengthen the module's basic concepts, learning to correctly use different interactive elements and controls, as well as the basic rules and good practices associated with developing usable interfaces. The third project (P3) proposes a more complex activity and it was during this project that the intervention was conducted. In addition to the aforementioned, this project includes accessibility concepts that universalises the interfaces proposed, creating designs that maximise accessibility and remove barriers for potential users with physical, cognitive and technological issues.

The main objective that this project sets out is to create a user interface with certain requirements and restrictions that allow students to explore the usability and accessibility problems that users often experience. More specifically, students were asked to create a touchscreen interface for an oven. An everyday electrical appliance was chosen so that students could explore this module's fundamental aspects, promoting user-oriented design as an essential work method. To this end, the application's potential user is very heterogeneous (age, sex and technical capacities) and the product is widely known by users, which have already assimilated a way to work with it. This creates a simulation, encouraging them to produce a more natural and approachable interface. Furthermore, the new interface would be incorporated into the oven on a small, 5-inch touchscreen. This restriction would condition the design decisions that the students make and enable them to explore usability and accessibility actions on specific interfaces covered in the module, such as smartphone interfaces.

The third project (P3) comprises two stages; each has a different objective, delivery date and separate evaluation. The first stage (P3/1 milestone in Figure 1) consists of designing the interface. Students must submit their interface designs and a functional description for the interface. The objective of this stage is to evaluate the design decisions that the students make. During the second stage (P3/2 milestone in Figure 1), students must develop the interface, which allows them to evaluate the interactive processes and the experience of the end user that they have proposed.

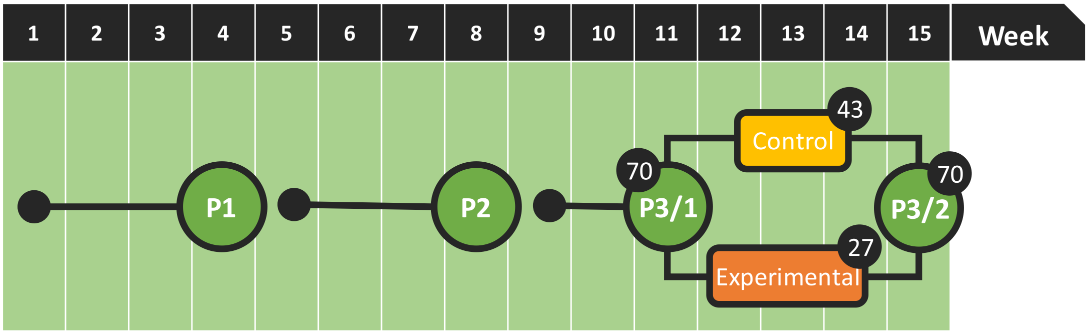

FIGURE 1. Academic calendar for the usability and acessibility module.

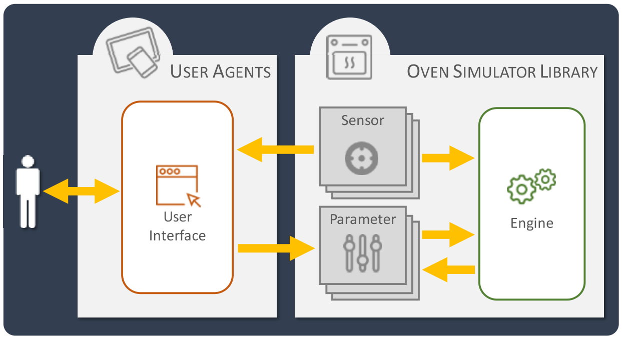

FIGURE 2. General diagram of the oven's management system.

Students must only use standard web technology to develop the project during this stage (HTML, CSS and JavaScript) so that the oven can be used from the integrated touchscreen interface and monitored and managed from any Internet-connected device. The objective of this is to strengthen usability, such as the interfaces' flexibility and adaptability and accessibility, such as device-independent access.

Students were given a JavaScript library, which simulates access to the oven's sensors and parameters (see Figure 2). The sensors monitor data related to the oven (e.g., temperature) while the parameters act on the oven's electronics (e.g., switching a given element on or off). The library has an engine that fully simulates the oven's functions, i.e., if the door is closed and an element is switched on, the temperature will gradually rise. If all elements are switched off, the temperature will drop, a process that speeds up if the door is open. This activity aims to make students more familiar with the reality of engineering project development.

Table 1 shows the oven's sensors and parameters. The library has an Application Programming Interface (API) so students can create an interface that can check the oven's sensors and modify the parameters.

Students have to submit a technical report on how to use the oven's API and a document detailing the functional requirements that the interface must include: cooking temperature selection, oven function selection, cooking timer, warning alarms (open door, long cooking periods, etc.), pre-set cooking selection, etc.

TABLE 1. Oven sensors and parameters.

Cat*	Name	Type	Description
S	External temp.	Number	External air temperature (ºC)
S	Internal temp.	Number	Internal air temperature (ºC)
S	Door	Boolean	Indicates the door's state: open (true) or closed (false)
S	Time	Date/Time	Data and time setting for the oven
S	Power consumption	Number	Oven's power consumption in watts
P	Upper resistance	Boolean	Switch the upper resistance on (true) or off (false)
P	Lower resistance	Boolean	Switch the lower resistance on (true) or off (false)
P	Grater	Boolean	Switch the grater on (true) or off (false)
P	Fan	Boolean	Switch the fan on (true) or off (false)
P	Beep	Boolean	Switch the alarm sound on (true) or off (false)

*Category: S, sensor; P, parameter.

B. INTERVENTION

The objective of the intervention was to prove the research hypothesis and to check that immersing students in more realistic situations during project development could lead to improved results, i.e., more usable and accessible products. To do so, 70 students were divided into two groups: a control group of 43 students who followed a traditional methodology and an experimental group of 27 students who followed the immersion method.

Both groups carried out the same activity for Project 3's design stage (P3/1); however, differences were set out during the development stage (P3/2). The control group students were only provided with an oven simulator library to develop the application (A in Figure 3). This library exposes the API to access the oven's functionality and uses keyboard commands so that the user can interact with the oven (for example, to open or close the door). The degree of immersion in this environment is very low, since the user does not interact with an oven and does not have a feedback on what his interface

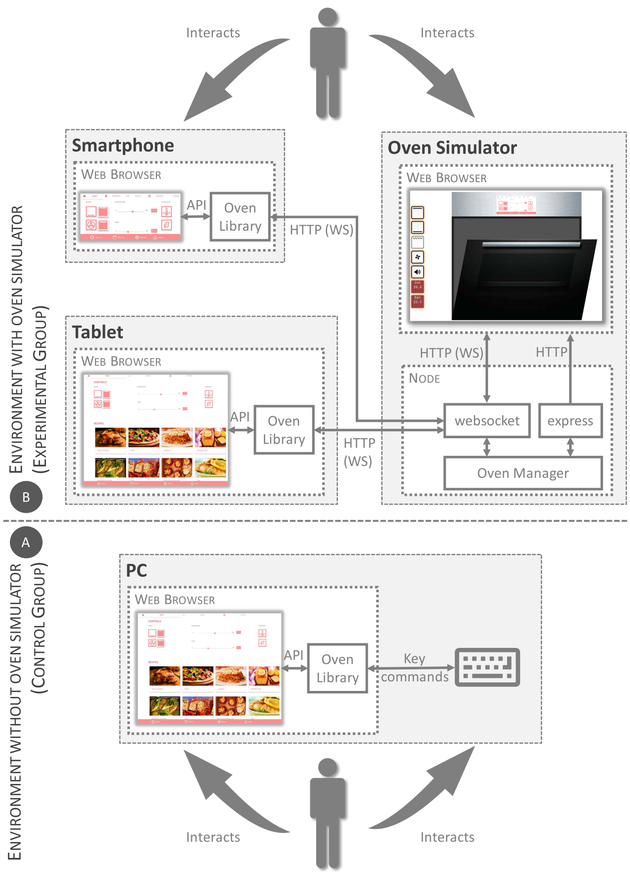

FIGURE 3. **Simulation environment for the experimental group (B) and the control group (A).**

is doing on it. On the other hand, the experimental group students were provided with a complete simulation environment, where the developed interface would be integrated in a virtual oven to which students could connect (B on Figure 3). The simulation environment uses web technology and is portable, meaning that students were able to work with it from home. Furthermore, experimental group students were encouraged to use the system away from the academic environment, using everyday devices, such as mobile phones, tablets and laptops and even involve friends and family members in the project development, ensuring better self-assessment of the product they developed.

The oven simulator was implemented in JavaScript via the NodeJS platform, given that it is a cross-platform environment that supports web standards. The oven manager was developed on this platform, which simulates an oven in operation, allowing access to the oven's sensors and parameters. Express (version 4.15.2) offers a website where the oven simulator can be viewed. The simulator always shows all of the oven's sensors and parameters and simulates a real oven's appearance and operations. For example, by clicking and swiping over the door, it can be opened or closed. The upper part shows the interface created by the student via an HTML iframe. The result is a realistic simulation of how the end product would work once it is manufactured. A two-way channel based on the WebSocket protocol was used to coordinate changes performed through the oven manager (temperature changes, door opening, element activation, etc.). In addition to the simulator, the channel can also integrate other external screens, such as mobile phones or tablets, where the oven's interface can be viewed. The WebSocket node module (version 1.0.24) was used to implement it.

Both groups (control and experimental) programmed the interface using the same tools, accessing the oven with the same API (Table 1). The only difference was the realistic immersion that the experimental group experienced through the virtualised environment, which placed those students in situations that are much more similar to the end users' experience. Through the simulator, the actions performed by the student in the user interface produce (through the library) a visual response in the oven simulator (for example, activating the alarm produces a beep or turning on a resistance, makes it light up with a warm color), and the actions performed by the user in the oven simulator cause (also through the library) to trigger events in the user interface (for example if the oven door is opened by pressing on it, the user interface is notified).

In order to ensure that the products developed by the students are successful, in terms of usability and accessibility, and taking into account that many of them have never been end users of a furnace, they are instructed in the basic operation of a traditional oven. In addition, they are encouraged to make real use of their prototype, with all the programming sequence of resistances and times for cooking various recipes. With these same realistic procedures, the evaluation of the products by the teachers is carried out later. This allows students to become end users of their own product, and to evaluate the user experience using the designed interface.

III. RESULTS

A quasi-experimental ''with a non-equivalent control group'' design was adopted [39] with pre-test-post-test control groups. Consequently, the statistical procedure used the general linear model with repeated measures. The time of assessment (pre-test and post-test) was used as the intra-subject factor, and participation in the project (belonging to the experimental or control group) was the inter-subject factor. All statistical analyses were conducted using SPSS (version 23.0).

In the case of the pre-test assessments, the usability of the proposed design has been evaluated. This evaluation was prior to the intervention, and was carried out stablishing objective criteria on the fulfillment of the design made with the usability directives studied in the subject: Ease of learning, Flexibility, Consistency, Robustness, Recoverability, Response time, Adaptation of homework, and decreased cognitive load. The evaluation in the post-test was focused on two fundamental aspects, the fulfillment of the proposed design and, therefore, the correct use of the usability principles, and the incorporation of accessibility rules. This evaluation is very objective, since it can be done automatically

TABLE 2. Test for inter-subject effects.

Source	Type III error	gl	F	Sig.	η^2 partial	Obs. power [a]
Intersection	6655.864	1	642.900	.000	.904	1.000
Group	35.526	1	3.432	.068	.048	.447
Error	703.995	68				

[a] computed using alpha = .05

TABLE 3. Test of intra-subjects effects.

Source	Type III error	gl	F	Sig.	η^2 partial	Obs. power [a]
Usability	3.028	1	3.716	.058	.052	.476
Usability * Group	6.079	1	6.079	7.458	.008	.099
Error (Usability)	55.421	68				

[a] computed using alpha = .05

using software tools, or it can be systematized with a revision of the delivered source code. The correction of the projects was carried out blindly, and regardless of which group each student belonged to.

The sample's normality test indicates a normal distribution. Box's M test shows homogeneity of the variance-covariance matrices ($p = .785$). To assess the programme's effect on students' performance, the students' grades were compared before (pre-test) and after the experiment (post-test). The independent variable or factor is belonging to one group or the other and the criteria or dependent variables are the grades obtained by the subjects at each stage of the project (P3/1 and P3/2). These students are graded in the interval [0-10].

The inter-subject test values (see Table 2) show that the average of all grades differed from zero since the tests were significant ($p < .000$) for intercept, but not for belonging to one group or the other ($p = .201$), which confirms that there are no significant differences between the student groups.

Table 3 shows proof of intra-subject effects with regard to programme application. Said test values show that the interaction effect between the time of the test (pre-test and post-test) and applying the programme with the new methodology is significant ($p = .008$). The power observed was .768, meaning that it is correct to reject the null hypothesis that the variances are equal. The effect size (η^2), proportion of total variation attributable to a factor or, the magnitude of difference between one time or another [40], which produces the interaction between the test time and the programme application is.099.

Finally, a t-test was conducted on the mean differences to check if there were any differences between the experimental group and the control group pre-test and post-test (Table 4). Table 4 shows that there are no significant differences at pre-test, meaning that both groups started under similar circumstances, as the inter-subject test already suggested.

With regard to the post-test, the test produced a significant difference between the two groups ($p = .008$). This difference represents 1.462 points more than the experimental group.

TABLE 4. Student's t-test on the difference in means.

Moment	t	gl	Sig.	Difference	Std dev.
Pretest (P3/1)	-,981	68	,330	-,606	,618
Postest (P3/2)	-2,741	68	,008	-1,462	,539

[a]. The parameter has been assigned the value zero because it is redundant.
[b]. computed using alpha = .05

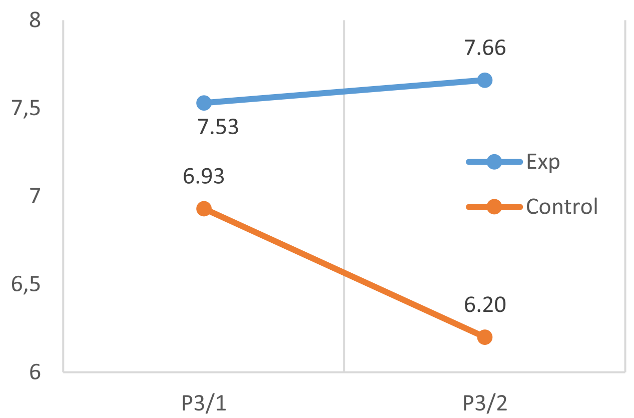

FIGURE 4. Average performance of the groups for the pre-test (P3/1) and post-test (P3/2) under scoring range [0-10].

IV. DISCUSSION

Information and Communication Technologies are changing the way we relate to the world. However, not all citizens are able to enjoy the benefits of using ICTs equally. The internationally recognised term Digital Divide highlights the inequalities that citizens face with regard to technology usage. This could be due to not having access to technology or not being able to make the most of the advantages that they offer us despite being connected. This research focused on the latter group, i.e., those who are affected by the "usability divide".

Usability divide can be observed from two approaches and mechanisms can be implemented to bridge the gap in both cases. From the users' point of view, digital literacy provides citizens with digital skills so that technology use does not represent an obstacle. From the ICT engineers' point of view, they must make sure that their creations are easy to understand and aligned with users' needs.

During this research, a new teaching methodology was developed for students on the Multimedia Engineering degree aimed at improving their usability and accessibility skills. Improving these skills will help improve the applications that these future engineers develop, making them more useful for users. This methodology places the student in the real world, in which students solve real problems that are significant and important to them and that are similar to the problems they will face in their professional future. This type of learning facilitates the transfer of the knowledge acquired and which will also last better over time [41]. This methodology is aligned with project-based learning in which satisfactory results have also been obtained for engineering students [42].

The methodological experience is based on making students become everyday users of their own products. This change has two objectives: to make the engineers become end users of their products and to encourage engineers to design a product that is very familiar to them. Improvements of this type have been reported previously, e.g., Marcos-Jorquera, Pertegal-Felices, Jimeno-Morenilla, & Gilar-Corbí [43] showed that end users' accessibility and usability skills improved when they participated in the product design alongside ICT engineers. Pan, Miao, Yu, Leung, & Chin [44] also showed that product familiarity improved the user experience, thus making it more usable.

The research reported significant differences between students that followed the methodology and those that continued to use the module's usual method. The experimental group achieved improved grades in comparison to their pre-test results, while the control group's grades were lower. The control group's lower grades are common for this module at the University of Alicante, given that the post-test is evaluated as being more complicated than the pre-test. Although there was no significant difference between the groups for the pre-test results, there was for the post-test, with the experimental group being 14% higher.

In the future, there are plans to improve the teaching of engineers by having them develop everyday products, not only for their personal use, but also for their friends and family outside the academic environment. This method aims to improve products' accessibility and usability characteristics. Other future research could be aimed at evaluating the impact Multimedia Engineering graduate students have on this methodology. Some of the variables that could be evaluated are motivation and teaching style. Reliability and validity psychometrics tests would be used for such (MAPLE, MSLQ, etc.).

In addition, it would be interesting to incorporate other approaches such as participatory design that could greatly enrich the learning process in the subject. However, this approach would imply the realization of group projects, and the number of samples obtained when performing the analysis of results would be drastically reduced. That is why, for this case, it would be essential to increase the number of participants in the study.

REFERENCES

[1] S. Zehle, "World summit on the information society," in *The Wiley-Blackwell Encyclopedia of Globalization*. Atlanta, GA, USA: American Cancer Society, 2012.

[2] WSIS Civil Society Plenary. (2003). *Shaping Information Societies for Human Needs*. Accessed: May 30, 2018. [Online]. Available: http://www.itu.int/wsis/docs/geneva/civil-society-declaration.pdf

[3] P. Norris, *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide*. Cambridge, U.K.: Cambridge Univ. Press, 2001.

[4] T. N. Friemel, "The digital divide has grown old: Determinants of a digital divide among seniors," *New Media Soc.*, vol. 18, no. 2, pp. 313–331, Feb. 2016.

[5] A. S. Santoyo and E. M. Martínez, *La Brecha Digital: Mitos Y Realidades*. Mexicali, Mexico: Uabc, 2003.

[6] P. M. Álvarez, *La Brecha Digital, Brecha Social. Los Recursos Humanos En El Desarrollo Y La Capacitación a TravÉS Del Aprendizaje Digital ('Elearning)*. Spain: Gazeta de Antropología, 2008.

[7] D. Buckingham, "Defining digital literacy," in *Medienbildung Neuen Kulturräumen*. New York, NY, USA: Springer, 2010, pp. 59–71.

[8] J. Edwyn, "Learning to bridge the digital divide," in *Organisation for Economic Cooperation and Development. The OECD Observer*, vol. 224. Paris, France, 2001, pp. 43–45.

[9] J. Castaño, J. M. Duart, and T. Sancho, "Una segunda brecha digital entre el alumnado universitario," *Cultura y Educación*, vol. 24, no. 3, pp. 363–377, Jan. 2012.

[10] P. van Seters, B. de Gaay Fortman, and A. de Ruijter, *Arie, and Department of Politics and Public Administration, Globalization and its New Divides*. Amsterdam, The Netherlands: Dutch Univ. Press, 2003.

[11] M. Kankaraš, G. Montt, M. Paccagnella, G. Quintini, and W. Thorn, *Skills Matter: Further Results From the Survey of Adult Skills. OECD Skills Studies*. Paris, France: OECD Publ., 2016.

[12] P. Best, R. Manktelow, and B. Taylor, "Online communication, social media and adolescent wellbeing: A systematic narrative review," *Children Youth Services Rev.*, vol. 41, pp. 27–36, Jun. 2014.

[13] E. Albrechtsen and J. Hovden, "The information security digital divide between information security managers and users," *Comput. Secur.*, vol. 28, no. 6, pp. 476–490, Sep. 2009.

[14] M. Beckedahl, "Much more could have been achieved," in *World Summit on the Information Society*. Johannesburg, South Africa: Association for Progressive Communications, 2005.

[15] *UNESCO ICT Competency Framework for Teachers—UNESCO Biblioteca Digital*. Accessed: May 24, 2019. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000213475

[16] *La Integración De Las Tecnologías De La Información y La Comunicación En Los Sistemas Educativos—UNESCO Biblioteca Digital*. Accessed: May 24, 2019. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000150785

[17] B. Farrand, "The digital agenda for Europe, the economy and its impact Upon the development of EU copyright policy," in *EU Copyright Law*. Cheltenham, U.K.: Edward Elgar Publishing, May 2014, pp. 988–1018.

[18] I. Peña-López, *Students, Computers and Learning. Making the Connection*. Paris, France Organisation for Economic Co-operation and Development, 2015.

[19] A. J. A. M. van Deursen and J. A. G. M. van Dijk, "Improving digital skills for the use of online public information and services," *Government Inf. Quart.*, vol. 26, no. 2, pp. 333–340, Apr. 2009, doi: 10.1016/j.giq.2008.11.002.

[20] J. van Dijk and K. Hacker, "The digital divide as a complex and dynamic phenomenon," *Inf. Soc.*, vol. 19, no. 4, pp. 315–326, Sep. 2003, doi: 10.1080/01972240309487.

[21] M. Ribble, "Passport to digital citizenship," *Learn. Lead. Technol.*, vol. 36, no. 4, pp. 14–17, 2008.

[22] A. Isman and O. C. Gungoren, "Digital citizenship," *Turk. Online J. Educ. Technol.*, vol. 13, no. 1, pp. 73–77, 2014.

[23] M. Ribble, *Digital Citizenship in Schools: Nine Elements all Students Should Know*. Washington, DC, USA: International Society for Technology in Education, 2015.

[24] F. Cruz-Jesus, M. R. Vicente, F. Bacao, and T. Oliveira, "The education-related digital divide: An analysis for the EU-28," *Comput. Hum. Behav.*, vol. 56, pp. 72–82, Mar. 2016.

[25] A. Lane, "The impact of openness on bridging educational digital divides," *Int. Rev. Res. Open Distrib. Learn.*, vol. 10, no. 5, pp. 1–12, Nov. 2009.

[26] B. Shneiderman, "Universal usability," *Commun. ACM*, vol. 43, no. 5, p. 85, 2000.

[27] D. D. J. Suwawi, E. Darwiyanto, and M. Rochmani, "Evaluation of academic Website using ISO/IEC 9126," in *Proc. 3rd Int. Conf. Inf. Commun. Technol. (ICoICT)*, May 2015, pp. 222–227.

[28] J. Nielsen, *Designing Web Usability: The Practice of Simplicity*. San Francisco, CA, USA: New Riders Publishing, 1999.

[29] A. Sonderegger, S. Schmutz, and J. Sauer, "The influence of age in usability testing," *Appl. Ergonom.*, vol. 52, pp. 291–300, Jan. 2016.

[30] A. Queirós, A. Silva, J. Alvarelhão, N. P. Rocha, and A. Teixeira, "Usability, accessibility and ambient-assisted living: A systematic literature review," *Universal Access Inf. Soc.*, vol. 14, no. 1, pp. 57–66, Mar. 2015.

[31] J. Nielsen, *Usability Engineering*. Amsterdam, The Netherlands: Elsevier, 1994.

[32] Y. H. Montero and F. J. M. Fernández, "Qué es la accesibilidad Web," *No Solo Usabilidad*, vol. 2, pp. 1–18, Jul. 2003.

[33] S. L. Henry, "Understanding Web accessibility," in *Web Accessibility*. New York, NY, USA: Springer, 2006, pp. 1–51.

[34] R. Baecker, K. Booth, S. Jovicic, J. McGrenere, and G. Moore, "Reducing the gap between what users know and what they need to know," in *Proc. Conf. Universal Usability CUU*, 2000, pp. 17–23.

[35] A. Holzinger, "Usability engineering methods for software developers," *Commun. ACM*, vol. 48, no. 1, pp. 71–74, Jan. 2005.

[36] E. M. Schön, J. Hellmers, and J. Thomaschewski, "Usability evaluation methods for special interest Internet information services," *Int. J. Interact. Multimedia Artif. Intell.*, vol. 2, no. 6, p. 26, 2014, doi: 10.9781/ijimai.2014.263.

[37] T. Øvad and L. B. Larsen, "Experiences from training agile software developers in focused workshops," in *Proc IHCI*, 2014, pp. 355–359.

[38] M. D. Merrill, "First principles of instruction," in *Instructional-Design Theories and Models: Building a Common Knowledge Base*, vol. 2, C. Reigeluth, Ed. New York, NY, USA: Routledge Publishers, 2009.

[39] D. T. Campbell and J. C. Stanley, *Experimental and Quasi-Experimental Designs for Research*. Ravenio Books, 2015.

[40] R. Ledesma, G. Macbeth, and N. Cortada De Kohan, "Effect size: A conceptual review and applications with the ViSta statistical system," *Rev. Latinoam. Psicol.*, vol. 40, no. 3, pp. 425–439, 2008.

[41] S. Vosniadou, C. Ioannides, A. Dimitrakopoulou, and E. Papademetriou, "Designing learning environments to promote conceptual change in science," *Learn. Instr.*, vol. 11, no. 4, pp. 381–419, Aug. 2001, doi: 10.1016/S0959-4752(00)00038-4.

[42] J. Mills and D. Treagust, "Engineering education,—Is problem-based or project-based learning the answer," *Australas. J. Eng. Educ.*, vol. 3, no. 2, pp. 2–16, Jan. 2003.

[43] D. Marcos-Jorquera, M. L. Pertegal-Felices, A. Jimeno-Morenilla, and R. Gilar-Corbi, "An interdisciplinary practical for multimedia engineering students," *IEEE Trans. Educ.*, vol. 60, no. 1, pp. 8–15, Feb. 2017.

[44] Z. Pan, C. Miao, H. Yu, C. Leung, and J. J. Chin, "The effects of familiarity design on the adoption of wellness games by the elderly," in *Proc. IEEE/WIC/ACM Int. Conf. Web Intell. Intell. Agent Technol. (WI-IAT)*, Dec. 2015, pp. 387–390.

MARÍA LUISA PERTEGAL-FELICES was born in Spain, in 1974. She received the B.S. degree in psychology and pedagogy from the University of Alicante, Spain, and the Ph.D. degree, in 2011. She is currently an Assistant Lecturer with the Department of Developmental Psychology and Didactics, University of Alicante. She also has more than ten years of child guidance experience at public schools. Her research interests include emotional intelligence applied to work performance, investigation of higher education, and the development of generic competencies.

DIEGO MARCOS-JORQUERA was born in Spain, in 1974. He received the engineering degree in computer science from the University of Alicante, in 1999, where he is currently pursuing the Ph.D. degree with the Department of Computer Science and Technology. He is currently an Associate Professor with the University of Alicante. His research interests are in the area of network management, computer networks, and distributed systems.

ANTONIO JIMENO-MORENILLA was born in Spain, in 1970. He received the Ph.D. degree from the University of Alicante, Spain, in 2003. He is currently a Full Professor with the Department of Computer Technology, University of Alicante. His research interests include computational geometry for design and manufacturing, rapid and virtual prototyping, and high-performance computer architectures. He also has considerable experience in the investigation of the professional skills of computer engineers.

RAQUEL GILAR-CORBI was born in Spain, in 1974. She received the Ph.D. degree in educational psychology, in 2002. She has been an Associate Professor with the Department of Developmental Psychology and Didactics, University of Alicante, Spain, since 2003. She is currently the Director of the Department of Developmental Psychology and Didactics. She has managed and participated in numerous research projects, both national and international. Her research interests are focused on intelligence, underachievement, high abilities, emotional intelligence, and teacher training.

HIGINIO MORA received the Ph.D. degree in computer science from the University of Alicante, in 2003. He is currently an Associate Professor with the Department of Computer Technology, University of Alicante, Spain. His areas of research interests include computer modelling, computer architectures, high-performance computing, embedded systems, the Internet of Things, and cloud computing paradigm.