Augmented reality application centered on the child as a resource in a virtual learning environment

Aplicación de realidad aumentada centrada en el niño como recurso en un ambiente virtual de aprendizaje

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Keywords
User centered design; augmented reality; usability; virtual learning environment; online learning

ABSTRACT

Given its characteristics, augmented reality (AR) is presented as an alternative resource in a virtual learning environment (VLE) by providing virtual elements in the real world, which can facilitate learning. This article aims to describe the development of a mobile application with guided AR under the fundamentals of UserCentered Design (UCD) in order to be integrated into a VLE. The development strategy consisted of using the UCD and in its phases making use of tools such as: surveys for the collection of information, Quality Function Deployment to identify and prioritize requirements, AR technology for prototyping and finally usability tests to identify design problems. As a result, it was possible to demonstrate the viability of this procedure in the development of interfaces of this type, considering that the resources that contextualize the needs and tastes of its users can provide better facilities and motivation within their learning. The case study studied is that of English for primary school children, which allowed verifying that this detailed framework can be replicated to other areas of interest and allow teachers to integrate AR applications in face-to-face or online learning environments.

Palabras clave
Diseño centrado en el usuario; realidad aumentada; usabilidad; entornos virtuales de aprendizaje; aprendizaje en línea

RESUMEN

Debido a sus características, la realidad aumentada (RA) se presenta como un recurso alternativo en un ambiente virtual de aprendizaje (AVA) al aportar elementos virtuales en el mundo real que pueden facilitar el aprendizaje. Este artículo describe el desarrollo de una aplicación móvil con RA, guiada con base en los fundamentos del diseño centrado en el usuario (DCU) para poder ser integrada a un AVA. La estrategia consistió en emplear el DCU y hacer uso de herramientas en sus fases, como encuestas para recolección de información, despliegue de la función de calidad a fin de identificar y priorizar requerimientos, tecnología de RA para el prototipado y pruebas de usabilidad para identificar problemas de diseño. Como resultado, se demostró la viabilidad de este procedimiento en el desarrollo de interfaces de este tipo, a partir de considerar que los recursos que contextualizan las necesidades y los gustos de sus usuarios pueden proveer mejores facilidades y motivación dentro de su aprendizaje. El caso de estudio trató del inglés para niños de primaria, que permitió verificar que este marco de trabajo detallado puede replicarse en otras áreas de interés y permitir al docente integrar aplicaciones con RA en entornos de aprendizaje presenciales o en línea.

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INTRODUCTION

Augmented reality (AR) may be represented as the integration of 3D virtual objects to real settings with the purpose of enhancing their perception within a non-immersive environment. Likewise, this considers part of what is cataloged as mixed reality (Pan *et al.*, 2006), which enables the transition between reality and virtual reality in a natural (Abdoli-Seizi & Bahry, 2015) and synchronic way, mostly supported by technological devices, such as mobiles (Liao, 2018), and with advantages in the educational area, such as students' motivation (Marin-Diaz, Cabero-Almenara & Gallego-Perez, 2018), as well as improvement of academic performance (Cabero-Almenara *et al.*, 2019), for this reason it has been used to teach languages (Redondo *et al.*, 2019), mathematics (Alvarez-Sanchez *et al.*, 2017), social sciences (Cozar-Gutierrez & Saez-Lopez, 2017), and medicine (Cabero-Almenara *et al.*, 2018), to mention some examples.

In the words of Abdoli-Seizi & Bahru, "AR is effectively in line with constructivist ideas of education [...] aimed to acquire understanding and knowledge" (2015, p.1). Thus, a resource as simple as a marker, as it is detected by an AR mechanism, may provide students with an encouraging and enjoyable experience that would enable multimedia visualization (audio, video or text) with 3D objects, and implementation of a topic with a certain degree of realism, without the development of complex interaction settings and only centered in essential elements that require the application as a function of the associated subject (Martinez & Dalgo, 2017). The foregoing, in turn, allows the understanding of concepts which, due to their abstract nature, need visual support for assimilation purposes (Kiat *et al.*, 2017).

Furthermore, AR innovation is not only conditioned to the manner content is presented, but how information reaches students in an intuitive manner, and they do it aware of their actual surroundings, but immerse in an alternative setting (Martinez & Dalgo, 2017); this increases their cognitive, spatial and perceptive-motor skills, regardless of the study level (Gil *et al.*, 2015).

Virtual learning environments (VLE) provide novelty interaction and content alternatives for the teaching-learning process and help students to show their skills aimed to analyze problems and to explore new concepts; in addition, they foster instantaneous participation with other students, they comprise a collaborative setting (Abdoli-Seizi & Bahru, 2015; Alvarez-Niño & Arias-Ortiz, 2014) and allow professors to select new communication and interaction strategies with their students by means of innovative learning experiences which, if done in class, would be difficult to execute (Kiat *et al.*, 2017). The main representation of these VLE is found in e-learning settings, fully resorted in online education (Pan *et al.*, 2006). Edel & Guerra (2010) emphasize on the capacity to foster students' responsibility for what, how and where they learn, and underline that their success depends on the resources included in class.

Herrera-Mosquera (2017) identifies two VLE categories: those purchased by educational institutions from private companies, where the professor configures his/her activities within the platform, as well as those, in a free software capacity, the professor can install on personal decision or, even, with the role as developer and create his/her own applications. Thus, VLE may be directed to the institution or to the professor (Walker & White, 2013). In the former, the professor should adapt to VLE and adjust his/her educational resources to available features by the platform and, therefore, to the thematic content prescribed by the institution, whereas the latter enable more convenience to design his/her activities and "play" with technological applications" (Herrera-Mosquera, 2017, p- 483).

Regarding its composition, Pan *et al.* (2006), quoted in Garcia *et al.* (2017), say that a VLE is comprised by constitutive and conceptual elements. The former refer to interaction media, resources and environmental and psychological factors; the latter outline aspects that define the educational concept of the virtual environment, which are the instructional design and the interface. Constitutive elements are crucial to attain an accurate visualization of knowledge, whereas conceptual elements provide a level of realism during the social interaction between the students and the professor, as strategies are included that favor the cooperation within the instructional design. Therefore, the essence of a VLE allows and challenges the construction of gradually more attractive settings from the point of view of interaction, so, during the study experience, the student is made to feel that he/she has control over his/her learning and therefore handles objects within a virtual space.

Content developed by using AR may become an educational resource and feed an innovative experience with attractive interaction mechanisms that are included in success factors during the implementation of a VLE (Pan *et al*., 2006), whether they fall on the kind for the institution or for the professor. These educational resources ought to be facilitators of the learning process and favor their autonomy, to reach the course objectives, to encourage inquiring activities, to attract the attention of students, to allow them to associate their prior experiences with the new knowledge, to contextualize it from its socio-cultural setting, to foster the thinking process aided by images and to promote creativity; all of this with the intention of creating favorable environments for the learning process where students may develop their own mental construction (Sejzi & Aris, 2012). For this purpose, didactic resources ought to have three main characteristics: to motivate, to carry content based on the topic and to be designed with its own structure (Edel & Guerra, 2010).

If we start from the idea that technological evolution has changed the way to learn among students due to access to technology, such as mobile devices, we would set the student's profile as a person with full proficiency at handling technology, which allows him/her to be motivated during his/her learning process, and to not show any resistance to adapt to technological changes, on condition that innovating experiences are provided (Rodriguez, 2016). Therefore, AR may be included in VLE as this is an attractive link for the user which contributes to the assimilation of new knowledge. In this respect, Abdoli-Seizi & Bahru (2015) emphasize that "using AR as a 3D device in a VLE would take the benefit of our skills to observe objects" (p. 3), which favors the integration of new technologies in the educational setting which promotes perception and interaction with the real world without involving the use of real objects (Martinez & Dalgo, 2017).

An example of integrating AR resources in a VLE may be observed in an online course, where a thematic plan is managed with elemental multimedia content (readings, video, slides); in this course, evaluation and validation of learning of a topic may be complemented by using an AR application, in such a way that the student will only have to download the markers, print them and practice the topic as he/she visualizes the 3D objects. We would then be speaking of an innovative learning experience, where the teacher may verify that the student did the review as suggested to meet a specific score within the app, and that a screenshot is sent as evidence that he/she played and obtained the requested score.

In this sense, Abdoli-Sejzi & Bahru (2015) point out that AR may supply personalized VLE with contextual richness adjusted to the needs of its consumers, which allows a smooth transition between the theoretical and practical application of content, and center on how real and virtual resources are mixed to attain goals, needs and objectives of a specific thematic course. These arguments have been identified in projects such as GLUEPS-AR (Muñoz-Cristobal *et al.*, 2013; Muñoz-Cristobal *et al.*, 2012), E-bidia (Caro, 2014), enlazAR (Rodriguez-Rojas & Valencia-Cristancho, 2014), UNED-ARLE (Cubillo, *et al.*, 2015), ARvirtual (Buitrago-Pulido, 2015) and ARprende (Ramirez-Otero & Solano-Galindo, 2017).

Although there is no question about the advantages of AR for a VLE, the focal point of success in the integration of the two environments is concentrated in developing multimedia resources with AR which consider the likes, needs and interests of users for whom they are addressed, and to integrate contextual and socio-cultural factors to them so that they allow the user to permeate prior knowledge with the new knowledge in a natural or familiar way. Therefore, resource construction ought to demand a methodology that would support these aspects, whose role may be provided by models such as user-centered design (UCD) in accordance with the standard ISO-9241-210.

UCD is a development approach of interactive systems which "consists of a multidisciplinary activity that incorporates human factors and ergonomic knowledge, application of these activities to the design of interactive systems favors their efficiency and efficacy, improves human work conditions and reduces possible adverse effects to the use thereof on health, security and functional features" (AENOR, 2000, p. 1).

Wang, Elzakker & Kraak (2017) adopt the UCD approach for the conceptual design of an application in AR with the purpose of aiding students in obtaining a better understanding of the field work in human geography. Williams, Yao & Nurse (2017) developed an application with AR for touristic purposes by means of an interactive process of UCD which empirically evaluated the landscapes system of the city of Oxford, England. Based on the UCD cycle, Nunes *et al.* (2019) explore the use of AR in the preparation and in response phases in the event of disasters, while Alnabit & Indriasari-Mansor (2018) prepared a high-fidelity prototype in AR to support the administration of medications to senior citizens. On the other hand, Bruno *et al.* (2019) present an AR tool produced by means of UCD to detect and record variations of design in the oil and gas sector.

Thanks to these works, UCD is interpreted as an interactive methodology which provides the guide to develop user-centered applications (students or professors) who would use the resources (AR application) with the intention that it is efficient, effective and which they like. In turn, its interactive nature allows determination of the reiteration point from the new stage considered relevant, without overlooking all the other phases again when it has already been seen. This fact provides the possibility to know the mental model of who shall be the user and to provide the design and the organization of content within the resource, adapted to the specific needs of the sector it is addressed to.

In the scene presented herein, it is relevant to analyze the UCD follow-up for the construction of an AR application as an integrating resource of a VLE, specifically for teaching the English language. In accordance with Education First (2019), in a range of 80 countries, during the period of 2011-2018, Mexico went from the 18th place to the 57th place in the proficiency of the English language of non-native students. In addition, this has been shown as an area of interest known as mobile-assisted language learning (MALL), which represents a variation of VLE in mobile technology (Herrera-Mosquera, 2017).

This study is centered on elementary school children (grades 3 to 6), since, as mentioned by Quidel *et al.* (2014), teaching English at an early age fosters benefits for children by learning in a natural way. Based on the hypothesis of effectively integrating UCD with AR technology for the design and construction of a mobile application that may be incorporated as an innovative resource within a VLE, in this article we describe the process of a first UCD iteration in the development of this application for Android, with the purpose of providing a guiding framework for the preparation of student-centered multimedia resources, in this case, of infants.

METHODOLOGY

Below we detail the relevant phases of a first iteration in addressing the UCD work framework and its different phases. In figure 1 we formed the tools compendium to be included in every phase aimed to build a mobile application with AR.

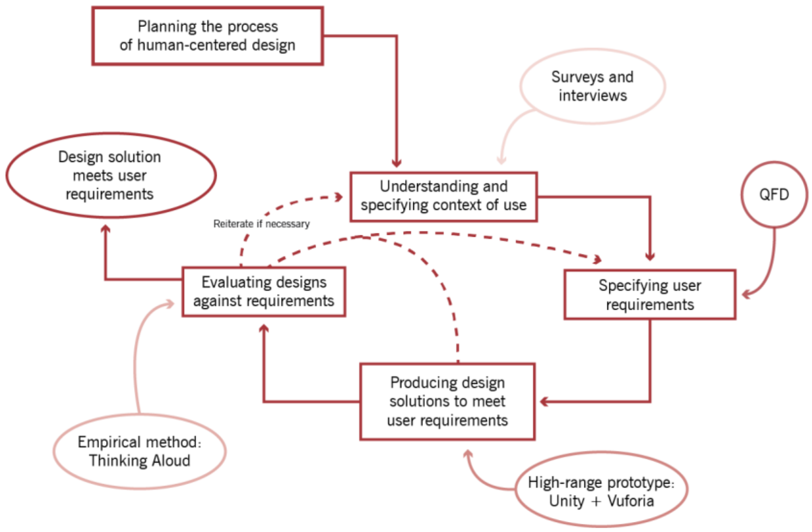


Figure 1. UCD methodology and tools integration.

Understanding and specifying context of use

With the purpose of understanding the activities done in the classroom to learn English (the work setting the child is involved in) and the link between the parent and teachers in instructing the student, we applied data collection instruments based on polls and interviews of the final user (the child), professors and parents.

Specifying user requirements

Functional and non-functional requirements collected by children in the previous phase represented access to this second phase, where the QFD is used (Akao, 1990), normally translated as "quality function deployment", an organized system to change the needs and wishes of the customers regarding product or service requirement designs. The purpose of this is to set a priority among requirements obtained, in addition to finding the tools that would provide the solution, and learn in what order they are to be addressed (Ruiz-Falco, 2009).

Producing design solutions to meet user requirements

In the third stage of UCD we used the results obtained from the QFD matrix to validate the development technology and prepare a high range prototype of the application called English AR; in this regard we employed a Unity development IDE (Unity Technologies, 2019) and a Vuforia plugin (Vuforia Engine Team, 2019), which allows the performance of a marker detection mechanism to handle them within augmented reality. The application is compatible with Android mobile devices.

Evaluating designs against requirements

For the last phase of UCD, we employed the usability test Thinking Aloud (Nielsen, 1993) to find errors of design and implementation, in addition to verifying the correct interpretation of requirements. The test we chose allows us to find this type of errors when it is applied to a few users (no less than three) and provides a high performance at a low economic cost; there is a disadvantage because of the high cost in time for its implementation. The result of using this test is a list of usability problems to be considered in a second iteration. The tests were administered to six infants (three boys and three girls) who met the user profile, and spaces were arranged in accordance as recommended by Lausen (2005).

RESULTS

In this section we describe the main results for every phase of the first iteration of UCD for the development of the quoted application.

Understanding and specifying the context of use

In order to collect enough contextual information, we performed a sampling estimate that would determine the number of boys and girls required for the polls, therefore, we took the sampling formula for infinite population (Casal & Mateu, 2003) with a level of confidence z = 1.96 suggested by these authors, probabilities of success (p) and failure (q) of 50% and a maximum admissible error of 5%; these values were established to obtain a fair estimate; 384 children were obtained as a requirement.

Survey requirements with children was divided in two sections: the first one was a pencil and paper poll, aimed to obtain information on their likes, affinities, opinions about the English class, favorite videogames, access to a mobile device, the manner they understand the English class and whether they are aware of apps to learn that language. We also showed videos on the applications with AR to the minors so that they were aware of the technology and then they produced an opinion in writing of what they wanted the application to have (functional and non-functional requirements). These opinions allowed crucial requirements to be formalized.

The second poll was answered on a webpage and comprised a weighting mechanism called Japanese scale (Ruiz-Falco, 2009), which goes along with the QFD procedure to favor the requirements approved by the student and to correct those that have not. In this regard, we incorporated figures to the webpage with the following expressions: happy, neutral, and sad, with scores of 9, 6 and 3, respectively; at the end of the test, we obtained a list sorted by priority of the suggested requirements. The results of the polls administered to the children allowed us to identify the functional requirements of the application, the mental model of the student about an English class (see figure 2), along with his/her user profile (see Table 1).

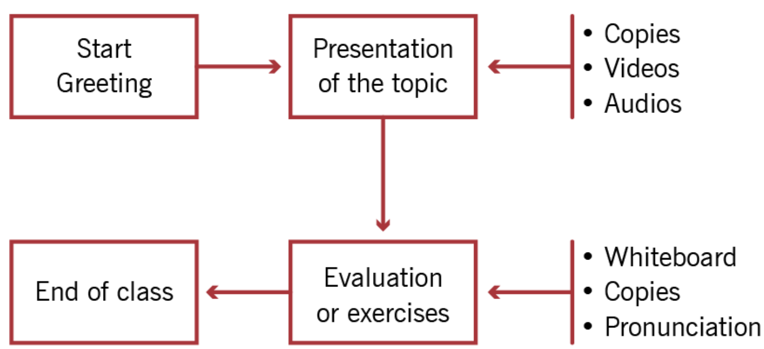


Figure 2. Mental model of user about an English class.

Table 1. User profile

Age	9 to 12 years old
Sex	Male and female
Physical limitations	Minor or non-existent hearing problems, minor or non-existent vision problems
Occupation	3rd to 6th grade student
Knowledge	It doesn't matter if they have or not any knowledge of English language
Skills	Reading and writing
Hardware they have used before	Cell phone or tablet with Android system
Interaction styles	Direct manipulation
Experiences with similar software	Duolingo, Open English Jr.

We obtained additional information aided by two English teachers at an elementary school level, by means of an interview on the proper thematic content for students, in accordance to the school grade they are in; for example, greetings and usual objects for the first grades, and for the more advanced, verb conjugations and text translation; in addition, information about how English classes are taught, with the purpose of encouraging students in class and, thus, to integrate one of said strategies in the application. As a result, we identified that, in a class, the teachers first explain the topic and then they carry out exercises or evaluate; in order to motivate their students, they do teamwork and reward them with participation points. The most used digital resources are videos and audios.

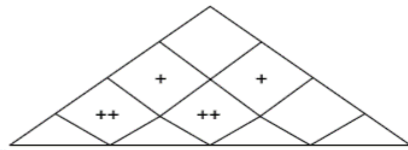
As a supplementary manner, we invited ten parents to learn about their opinion on the use of the application by their children by means of a poll which included nine open questions. Some of the questions inquired were whether they had any interest in knowing their children's progress in respect to the topics seen through the application, whether it was important to them that their children learned English, the estimated time they believed their children should be using the game, and the format in which the application ought to show their children's progress.

The result of the poll conducted reveals that 100% of the parents like the idea of an application to help their children in studying the English language; in addition, parents prefer their children to use the application in a time between 30 and 45 minutes, and say that they would like to know the daily time of use of the application.

The sample of English teachers and parents was determined from an intentional sampling because this "allows the selection of accessible cases whose inclusion is accepted. This, in the terms of the convenient accessibility and proximity of the subjects to the researcher" (Otzen & Manterola, 2017, p. 230).

Specifying user requirements

Figure 3 shows the QFD developed to obtain user requirements. The list of "whats" is the requirement obtained from the poll conducted on the children, and they are grouped in three main features: portability, nice view and ease of use. These categories were proposed because the sum of requirements achieves a common end. The "hows" are in the upper sections of the columns, and they are the tools and methodologies to be used to solve the "whats". The "hows" were proposed on the basis of a research and comparison of different alternatives; they were sorted out by priority, integration of the development in Unity with AR, the databases and UCD to obtain the most frequent requirements (whats).



¿Qué debe tener una aplicación para motivar el estudio del idioma inglés en niños?			Realidad aumentada	Programa-ción Unity	Bases de datos	DCU	Evaluación de la competencia	
							Duolingo	OE Jr
Portabilidad	Usar en el celular	9		9			9	1
	Usar en la tablet	1		9			9	1
	Sin internet	9			9		1	1
	Diferentes niveles	3		9		3	3	1
Vista agradable	Animaciones	9	9	3		3	3	1
	Traducciones	3		9	3		9	9
	Pronunciaciones	3		9	3		9	9
	Recompensas	3		9	3		3	1
Fácil uso	Instrucciones	1				9	3	1
	Dificultad		5	5	3	3		
	Puntuación absoluta		405	1125	324	134		
	Puntuación relativa		20.37	56.59	16.30	7.74		
	Prioridad		2	1	3	4		

Figure 3. QFD matrix for English AR.

Regarding the "competency" application and as a result of the polls on children, we identified Duolingo and Open English Jr.; later on, the developer determined, on the basis of the Japanese scales, the weighing these applications ought to have. The application with the best score between the two was Duolingo, therefore, these were the parameters of reference which the new product ought to meet or, even, improve.

Producing design solutions

The English AR architecture, along with the technologies used for the development, is shown in figure 4; here, the student has access to a PDF document which contains 20 markers and makes use of them (1, 3, 4); the markers are located by the "Marker Detection Mechanism" comprised of the device chamber (5); the Vuforia plugin and the markers' database (6). Once it has been identified, the associated object may be seen within the user interphase (7), which makes constant inquiries on the user database (2, 8), performed by the database manager SQLite (SQLite Consortium, 2019). The foregoing was programmed by means of the Unity IDE in C# language.

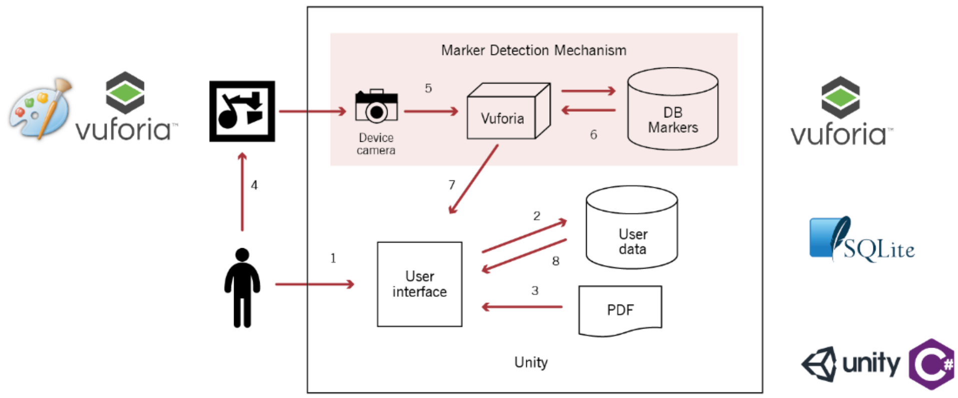
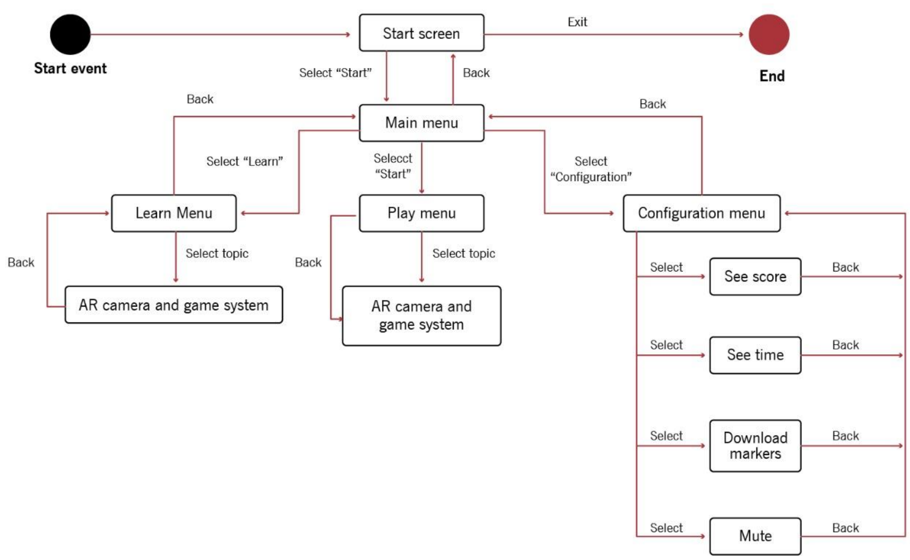


Figure 4. Architecture of the English AR application.

In the state diagram of the English AR application presented in figure 5, we can see the navigation between screens, which represents a distribution guide and the way to follow in order to execute the different tasks allowed.

Figure 5. State diagram of the English AR navigation.



In figure 6, we show some of the interface screens of the English AR application, in addition to examples of augmented reality of the two categories (animals and fruit) considered in the high-range prototype.

Figure 6. English AR screens.

Evaluating design against requirements

To conduct the usability test, we prepared a plan suggested in Lauesen (2005) and established ten tasks so that the user would navigate throughout the whole application and was able to find mistakes of design and implementation. In the test plan we defined the total time per user of 230 minutes.

The tasks in the usability test were as follows:

- This is the first time you are going to use the application and you need to fill in your information; how would you do this?
- You need to download markers for correct interaction with the application; what would be the steps for this action?
- You have free time in the day, and you wish to study writing and pronunciation of fruits; how would you do this process?
- This is the time to put what you have learned to the test as you practice with markers; now, you have to test your

knowledge and relate the markers of animals with their names; what would you do to achieve this?
- You want to practice writing the names of fruits in English a bit; what is the way to do it in order to achieve this objective?
- You wish to study with the application at a quiet place; what would be the proper procedure for this action?
- Your parents are asking about the application and wish to see the daily time you spend on it; how would you show them this information?
- You have free time in the day, and you wish to study writing and pronunciation of animals, how would you do this process?
- After studying with animal markers, you put the knowledge you learned to the test when writing the correct names; once you have done this, you wish to know your total number of points you have; what is the procedure to follow?
- You have spent a lot of time in the application in the day and you wish to log out of the game without using the quick buttons of the mobile device; what steps should you follow to log out of the application?

Once the test has been applied to the six children, the output we obtained was the following list of usability problems:

- P1: Could not download the markers.
- P2: Could not disable the sounds.
- P3: Could not see the time used in the application.
- P4: Could not see the total score in a quick way.
- P5: Could not fill in user data.
- P6: Could not do writing practice of the objects.
- P7: Could not related markers with their names.
- P8: Could not log out of the application.
- P9: Could not have access to options because there were not images on the buttons.
- P10: Animations would not be observed well because of the size of markers.
- P11: Could not identify "which" markers correspond to "what" topic.
- P12: Names assigned to areas or sections do not describe clearly what they are for.

Next, we assigned a classification to each identified problem as established by Lauesen (2005). The total list of usability problems, its frequency and classification found during the test are shown in table 2.

Table 2. List of problems of usability identified in order of priority.

Problem	Overall classification	Solution
P1	Failure in homework	The option "Descargar marcadores" ["Download markers"] should appear in "Aprender" ["Learn"] or on the main menu
P7	Problem	Change the word *relacionar* [*relate*] for one that describes better the task to perform
P4	Problem	The option "Ver puntos" ["See score"] should appear on the main menu
P5	Problem	This option should appear on the main screen or in the main menu
P3	Minor problem	The option should appear on the main screen
P6	Minor problem	Change the word *escribir* [*write*] or add instructions in the main menu to know what the section contains
P2	Minor problem	Should have an icon for easier identification
P8	Minor problem	There should be a button to exit quickly
P9	Minor problem	Add icons to the buttons to make them more descriptive and easier to identify
P10	Minor problem	Every marker should be small to allow good visualization of animations

P11	Minor problem	Place the initial or name of the category in the bookmark
P12	Minor problem	Change some words which could cause confusion for the user and, moreover, the new words should describe the functions to which they are related

DISCUSSION

On the results obtained in the design evaluation, it is possible to quote some differences. In figure 7 it may be corroborated that the P1 usability problem is the only one six users recognized; P1 was identified after the students wanted to do task 2, which consisted in downloading the markers through a document in PDF format which was as a hyperlink in the app under the "Configuration" section (see figure 5), while they went directly to the "Learn" section because they expected to find them there; therefore, as this is such an important task to use the application, it was classified as a task failure, since, without markers, the application would be rendered unusable.

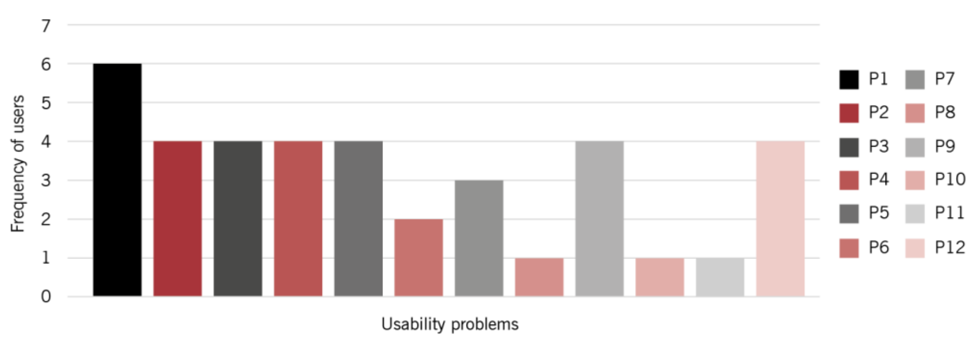


Figure 7. Number of users who identified each usability problem.

Likewise, we noticed that six usability problems (P2, P3, P4, P5, P9 and P12) were recognized by four users, of which, most of them were classified as minor problems, because they were done with a small-time delay. Problems P8, P10 and P11 were only identified by one user; it must be emphasized that these problems do not have a direct influence on the operation of the application, but they are relevant to apply possible improvements both in the visual and the conceptual aspect.

In figure 8, we can see that the user providing the most information for improvement was U2, as a total of nine problems of usability were found; the user that provided the least information was U6, with three usability problems.

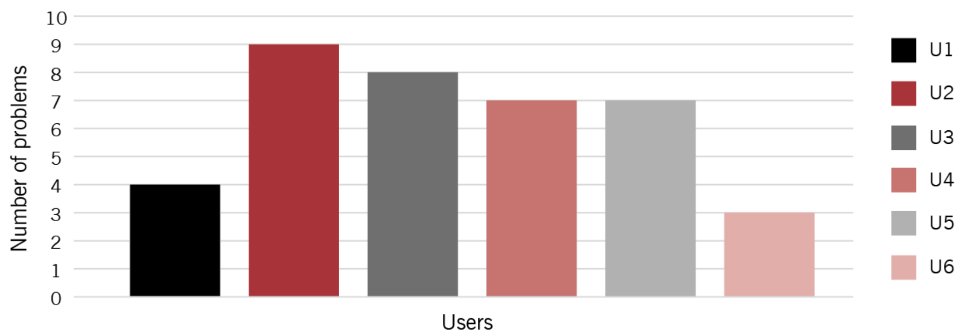


Figure 8. Usability problems detected by one user.

Figure 9 shows identification of eight minor problems, three mean problems and one problem classified as a task failure. The fact that a large part of recognized problems of usability are minor and that there only is one task failure shows that the interpretation of the mental model of the user and that the stated requirements, as a whole, were reflected correctly within the application.

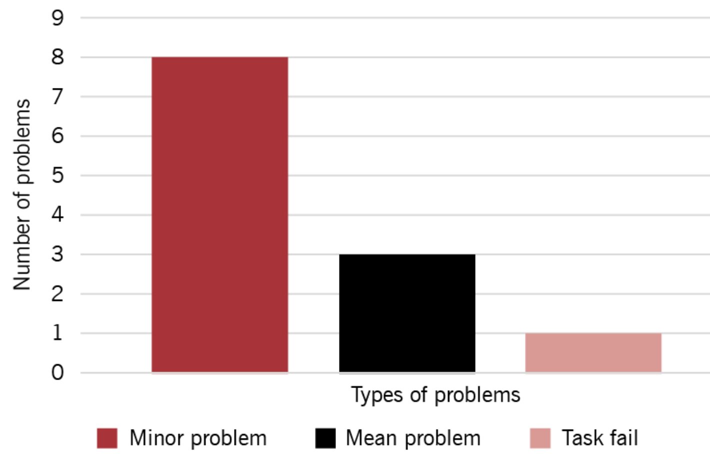


Figure 9. Usability problems per their global classification.

In figure 10 we can see that U2 provided more mean problems and, so, U2 and U3 detected more minor problems; only one identified more than 70% of the total usability problems.

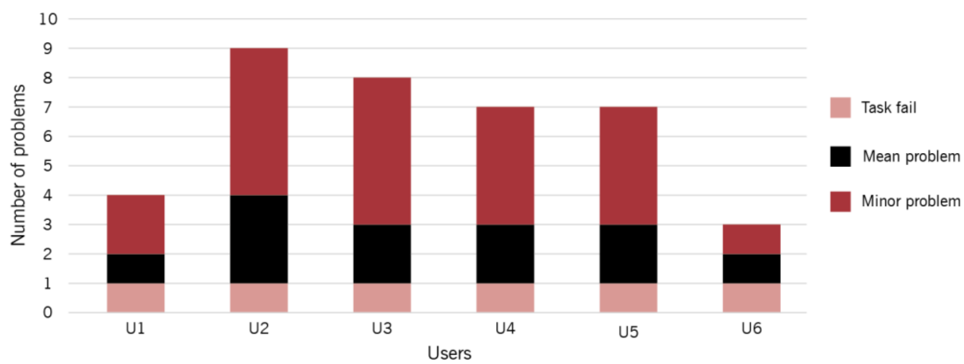


Figure 10. Usability problems found per user and their classification.

With regards the result of the methodological process described above, although there are works like those of Zhou, Cheok & Pan (2004), Prada & Uribe (2013), Del-Cerro & Morales (2017), Rodríguez (2016), and Mesquida & Pérez (2018) who propose resources with AR that may be included in a VLE, the products generated do not consider likes, preferences and interests of the students; for example, Lee *et al.* (2017) develop a mobile application prototype to teach English vocabulary to preschool students; the foregoing notwithstanding, evaluation is limited to consider parents with and without children in preschool level, and leaves the role of the child aside as a final user.

Meanwhile, Dalim *et al*. (2016) present an application with AR as a tool to teach basic words in English (colors, forms and prepositions) to non-native children of the language. The results show greater enjoyment of students as they use methods based on AR; however, they mention problems of usability that are not listed and that may be attributed to the fact that, unlike English AR, the students are only considered in the evaluation.

Because of its scope, the English AR application only is a first iteration product, which limits the likelihood of an immediate integration of a VLE. It is evident that the application of the 'thinking aloud' test allows a rapid appreciation of the quality of the product; notwithstanding, its disadvantages lie in investing time for its implementation. On the other hand, the methodology and the tools used facilitate iteration of the product, which favors exploration of the subsequent iterations of other assessment strategies for refinement. An extension of contents and, therefore, their integration as a resource in a VLE, or even in a didactic unit in a classroom-attendance course are some opportunities for improvement.

CONCLUSIONS

If we start from the technical and operational observed feasibility, it is possible to state that an application with AR developed by means of the UCD methodology may be a viable resource to be included in a VLE, as this corresponds to the characteristics typical of these environments; therefore, as it is centered on the child, the application will be adapted to the educational setting of this user; for example, English AR may be used as a resource within the instructional design of the teacher in a subject such as English at an elementary school level, and that it is the teacher who is to decide the moment to use the application in relation with the topics of study in class, whether in the classroom or virtually.

Thus, the contribution to this work lies in identifying and integrating technologies and methods, based in the framework of UCD, for the development of a mobile application such as a resource within a VLE aimed to teach the English language. It should be noted that the procedure detailed in this article presents a generic nature with the purpose that it is applied to topics different from that of the English language, or to integrate compatible technologies with other operational systems like iOS.

As a future line of work, we established a second iteration to consider pedagogical assessment of the resource, by means of instruments that make it possible to analyze outstanding factors in literature, such as motivation and education gain, or, to make a comparison between control and experimental groups.

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