An Augmented Reality-based mLearning approach to enhance learning and teaching: A case of study in Guadalajara

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Abstract. Augmented Reality (AR) is one of the most widespread technologies used in education, and many researches have been published proving its effectiveness. In recent times, the use of AR has been fostered through the use of mobile devices (smartphones), giving rise to what is called *mLearning* (mobile learning), with the aim to enhance the educational experience at all levels. Most of AR-based mLearning systems have been developed from a software development perspective, without the involvement of educational stakeholders to provide the content to show to students. On the other hand, many other researches propose solutions to cover specific educational requirements, but they completely forget about the acceptance of end-users (*e.g.* students). This paper presents an approach to assist in the development of AR-based mobile learning systems. The approach presents a methodology to guide the procedure to deploy an AR-based system, where different stakeholders are involved. In addition, a contribution of the approach is a survey to validate the user acceptance of AR-based mobile applications. To support our approach, most educational know-how and needs to improve in education through ICT were gathered during this research alongside the Polytechnic School "Ing. Jorge Matetu Remus" (Guadalajara, Mexico). For this educational center we have developed *cuceAR*, an AR-based mLearning prototype application to enhance teaching and learning as an example and a contribution of the approach.

Keywords: education · augmented reality · mobile learning · survey · technology acceptance model · methodology

1 Introduction

Education, as a cornerstone in the society, has been during the last years and decades a hot topic in ICT (*Information and Communication Technology*), due to its benefits and the promising enhancement of educational parameters through the use of the technology [1]. Many ICT-based solutions have emerged during last years [2], and several organisations have focused their attention to ICT applied in education [3].

One of the most widespread used technologies is Augmented Reality (henceforth *AR*), which has been widely accepted in society since its inception in several areas, not only education [4]. AR enables the combination of the real world with virtual objects, overlapping multimedia information in real time [5].

Along with AR, a trendy topic in ICT-based education proposals is mobile learning (also called *m-learning or mLearning*), that is, the use of mobile devices to enhance the educational experience at all levels [6]. Many AR-based mobile learning researches have been carried out in education showing their benefits against traditional learning environments in many different countries [7].

In Mexico, like in many countries in the world, several studies have been conducted to check the quality of education at all levels. For instance, the Secretariat of Public Education (*SEP*) in Mexico warned about loss of quality education during the period 2016-2017, with a failure rate of 4.9% in middle school and 13.7% in high school [8]. Other studies, like the conducted by Rodriguez et al. [9], point out the reason as the lack of individual study habits of the student, as well as the lack of teaching strategies by teachers. Thus, the benefits from the use of mobile learning and AR technologies can significantly enhance the quality education in Mexico, as shown through numerous related researches in other countries [10, 11].

However, the development of AR-based mLearning solutions is not a simple task, requiring the involvement of educational staff to target the educational requirements, the development of mobile applications that cover these requirements and support required functionalities and techniques and tools to ensure the end-user acceptance of the applications, with the aim to ensure AR-based solutions are suitable for education compared to traditional educational approaches.

In this paper we present an AR-based mobile learning approach with the aim to enhance learning environments. This approach presents 1) a methodology to address the study of educational environments where AR-based mobile learning technologies can improve quality of education; 2) *cuceAR*, an AR-based mobile application to cover educational needs developed for a specific educational center; and 3) a survey for the validation of AR-based mobile applications through TAM (*Technology Acceptance Model*). We have developed our approach using the know-how about educational requirements obtained in the Polytechnic School "Ing. Jorge Matetu Remus" (Guadalajara, Mexico), which served as case of study.

The remainder of this paper is organized as follows. Section 2 presents the related work. Section 3 introduces the approach and presents the methodology proposed to address the startup of AR-based mobile learning solutions. Section 4 shows *cuceAR*, an AR-based mobile app to cover the needs and enhance the education in the educational center used as case of study. Section 5 introduces the survey proposed for the validation of AR-based mobile applications. Finally, Section 6 summarizes the conclusions and further work.

2 Related Work

During the last years many researches and studies have been published showing the benefits of the use of AR in mobile learning applications against traditional educational approaches. For instance, the project presented in [12], which shows several researches where AR-based application have been used for educational purposes with promising results, compared to traditional educational approaches.

About the application of AR-based mobile learning approaches in the Mexican education system, one of the most highlighted project is the presented in [13], where an AR-based mobile application was used in-the-wild with a set of students with satisfactory outcomes.

In addition, in the literature there is a wide variety of AR-based mLearning researches applied to education at different academic levels[14]. For space limitation, it is not possible to compare the present proposal with the most relevant ones. Nonetheless, these researches exhibit common drawbacks, summarized as follow:

1. *No requirement analysis phase.* Many researches and AR-based applications for educational use are developed without the involvement of educational staff, who has the know-how about educational needs.
2. *Level-oriented.* Elementary and university are the main educational levels addressed, leaving the upper middle level behind.
3. *Static educational content.* AR-based mobile applications are developed to display specific and static content, hindering the customization of content for students.
4. *No user acceptance testing.* Most researches usually focus their attention in development and software engineering issues, forgetting about the user acceptance of the application.

Thus, in this paper we address these drawbacks, proposing an AR-based mLearning approach based on different elements, which are described in the rest of this paper.

3 Approach to enhance learning and teaching through Augmented Reality and mobile computing

3.1 Introduction

The enhancement of teaching and learning in education through ICT is a complex task where many stakeholders and technologies are involved. Educational staff as well as students are the know-how carriers, which can detect the issues or aspects to enhance in educational tasks, while technology could be the way to provide solutions for these educational issues/aspects.

Due to the different challenges presented in this development process (from know-how to a ready-to-use AR-based mLearning system), we present in this paper an approach with the aim to help in this development process. The approach has three different elements:

1. *Methodology.* A set of stages identifying in each one the stakeholders involved, the required input and the expected outcomes.
2. *AR-based mobile application.* As an example of AR-based technology, we present *cuceAR*, an application prototype developed according to educational needs detected in a specific educational institution, the Polytechnic School "Ing. Jorge Matetu Remus" in Guadalajara (Mexico).
3. *Survey to evaluate user acceptance.* Finally, a survey based on TAM (*Technology Acceptance Model*) is proposed as tool to validate AR-based mobile applications for education, in terms of user acceptance.

This approach has been developed using the know-how obtained from the Polytechnic School "Ing. Jorge Matetu Remus", where educational staff and students have contributed identifying educational needs.

In the rest of this section is presented the methodology. The AR-based mobile application is presented in Section 4 and the survey is explained in Section 5.

3.2 Methodology for the development of AR-based mLearning systems

Figure 1 shows an overview of the methodology, illustrating the different stages, the stakeholders and elements involved, as well as the required input and outcome of each stage. Although this methodology has been illustrated as a sequential process to clarify the design, the methodology has been envisaged as a sequential, linear and iterative approach, where the different stages can be carried out repeatedly.

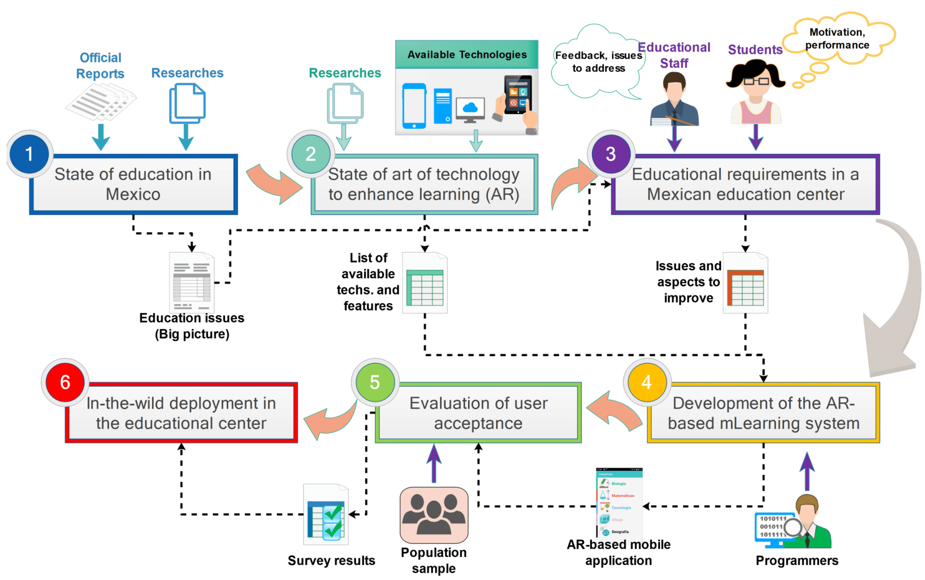


Fig. 1: Methodology for the development of AR-based mLearning systems

During our research, we carried out teaching assistant tasks in the Polytechnic School "Ing. Jorge Matetu Remus" (Guadalajara, Mexico), interacting with the different stakeholders related to education (educational staff and students) in order to detect the aspects to improve in their daily educational tasks. This knowledge helped us to comprehend educational needs and how the technology can cover them, helping in the design of this methodology. The explanation of the different stages of the methodology, within the framework of this collaboration, is shortly described as follows.

The methodology starts with the research about the state of education in Mexico. Through this stage, and using academic researches and official reports (such as those briefly described in Section 2), we got a *big picture* about the education issues in Mexico.

In order to find proposals to enhance the education and solve these educational issues, we carried out a systematic review of the technologies available in the second stage, focusing in AR as core technology of our proposal. In this stage, we did review many papers (some of them described in Section 2) as well as commercial AR-based technologies that can be applied to education (libraries, toolkits), with the aim to determine benefits provided by AR technology in the education as well as the most suitable software to build AR-based mobile applications.

In the third stage, few months were required carrying out teaching assistant tasks in the the Polytechnic School "Ing. Jorge Matetu Remus". Using the big picture obtained in the first stage of the methodology as background, during this stage 1) we did hold several meetings with the educational staff; 2) we reviewed the *syllabus* of the telecommunications studies; and 3) through several talks with students we got their impressions about the current state of education and their educational needs. As a result of this stage we achieved two main goals: 1) get the point of view of professors (as educators) as well as the students about the use of ICT and AR-based solutions and how beneficial it can be as a support tool in the classroom; and 2) a set of desired features to support educational needs such as the real-time access to information, localized access to any data source and the proper dissemination of concepts and artifacts that are not available in the facility resources, among others.

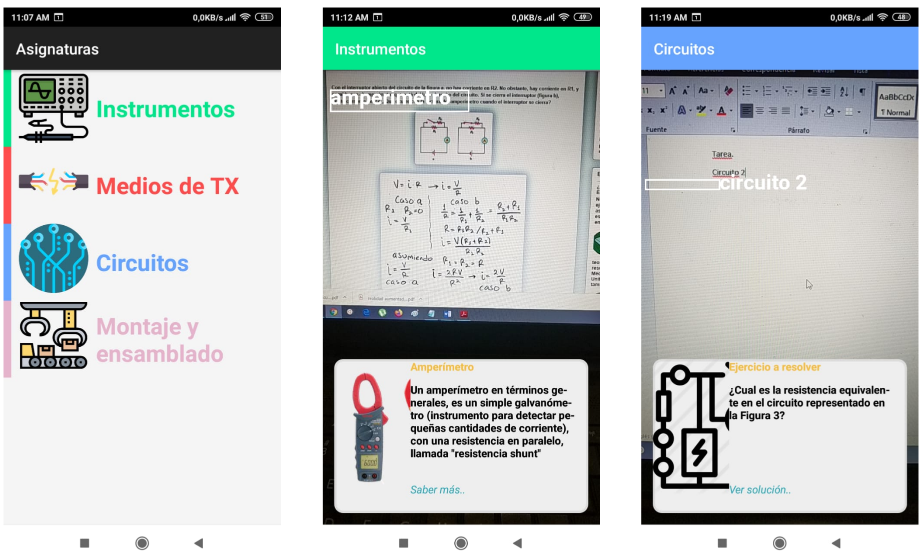
The fourth stage focuses on the development of the AR-based mLearning system by developers/programmers, using the right choice of the AR technology (stage two outcome) according to the aspects to improve in the educational center (stage three outcome). In this particular case, we have developed a specific AR-mobile, *cuceAR*, which is explained in Section 4.

The user (student) acceptance of the technology used to enhance the learning and teaching is quite important. In this way, we propose a survey based on TAM (*Technology Acceptance Model*) to validate the user acceptance of AR-mobile applications, which is depicted and explained in Section 5.

Finally, once the application has been validated (user acceptance testing), the entire AR-based mLearning solution should be deployed into the educational center (sixth stage).

4 cuceAR: An AR-based mobile application to improve education

As outcome of the fourth stage of the methodology, and in our particular case at the Polytechnic School ”Ing. Jorge Matetu Remus” (Guadalajara, Mexico), we have developed *cuceAR*, an AR-based mobile application that aims to be a support tool for students in telecommunication studies, allowing the access and search of additional information about their academic activities (Figure 2).



((a)) Subjects/Courses ((b)) Measurement Tools ((c)) Electronic Circuits

Fig. 2: cuceAR Mobile application

Through *cuceAR* the students are able to access the available content for the different subjects of the *syllabus* (listed in Figure 2(a)). For each subject there are *terms* (words) predefined by the professor. These terms, detected through AR-based technology (Figure 2(b) and 2(c)), allow students to get additional information to solve doubts and expand knowledge about a specific topic, displaying Youtube Videos, Wikipedia entries, online documents, etc.

cuceAR, as an educational resource, support the needs detected for this case in the Polytechnic School ”Ing. Jorge Matetu Remus”, but also could be applied in any institution with the same requirements. So far, *cuceAR* is in an early stage of development (prototype), however, the following technological guidelines will be considered during the development life cycle:

– *Service-Oriented design*. The entire system will be developed following a service-oriented design to ensure their extensibility, where new services could be added at anytime to support new functionalities [15].

- *Cloud-oriented.* The entire system will be supported by cloud technology, ensuring the scalability of the system and enabling the access to the information in real-time, anywhere and anytime [16].
- *User authentication and identification system.* Through an identification system it could be possible to track the terms searched by a specific student. This aggregated data could be very helpful to educational staff.
- *Cross-platform software. cuceAR* will be developed for iOS as well as web platform to widespread its use.

These technological guidelines in the development life cycle bring many benefits, such as scalability, extensibility and real-time access to information, among others. Thanks to these benefits and the technology used, many different key functionalities could be supported in order to enhance teaching and learning, highlighting:

- *Delocalized use.* The application could be used anywhere, indoor (classroom) as well as in outdoor learning environments, fostering its use and the interest in learning educational-related concepts by students.
- *Common technologies to foster education.* Vast majority of people have a smartphone device with Internet connection, including students. This situation could be exploited to foster the motivation of the student through a friendly mobile application.
- *Learner-centred approach.* The application proposes new ways of interaction in classroom, since it breaks with the traditional classroom environment where only the teacher teaches, reducing the gap between professor and students.
- *Real-time Interactive learning.* Through cloud technologies and services could be possible access to information in real time.
- *Retention of knowledge.* The student can use the application to expand and retain their knowledge through multimedia content, making the classes more interactive.
- *New resources.* Through the application could be possible access to new information not available in the facilities (*e.g.* oscilloscope, devices, assembly process).

To sum up, the benefits provided by *cuceAR* can enhance teaching and learning in educational centers, specially in the Polytechnic School ”Ing. Jorge Matetu Remus”, where the application is oriented to.

5 Survey to validate user experience in AR-based mLearning applications

As an outcome of the fifth stage, we propose a survey to measure user acceptance of AR-based mobile applications by the students.

The survey has been designed following TAM (*Technology Acceptance Model*), which can predict and explain efficiently the intention and behavior of users related to the acceptance of a particular information system [17].

Table 1: TAM-based survey for user-acceptance validation of AR-based mobile apps

Question	Score
Verification of the perceived *usefulness* variable	
The application would facilitate a better understanding of concepts and techniques	
I think the application is an useful tool to be used in class	
Through the use of the application I can improve my learning process and performance in the different subjects	
Verification of the perceived *ease of use* variable	
The application is easy to use and does not require prior technical knowledge	
Learning to use the application is easy, it doesn't take much time	
Verification of the *attitude toward using* variable	
The application makes learning more attractive and stimulating	
I got bored using the application	
Verification of the *behavioral intention to use* variable	
The use of applications based on augmented reality will make me feel more motivated in class	
Forthcoming semesters I would like to use the application in the classroom	
I would like to use the application as a support tool for self-study hours at home	

TAM is oriented to the use of questionnaires to measure the ease of use and usefulness of a technological tool. According to the literature, the elaboration of the questionnaires should reflect the validation of four variables: 1) *perception of usefulness*, 2) *perception of ease of use*, 3) *attitude toward use* and 4) *the behavioral intention to use* [18].

The survey, presented in Table 1, is organized in four blocks, one per each variable to be validated. Each block contains several *easy-to-answer* questions where each one is rated using *Likert scale* [19], which values may vary from 1 (totally disagree with the statement) to 5 (strongly agree with the statement).

Furthermore, the application of the survey proposed require the population sampling. In order to calculate the proper sample size for the survey, we suggest the use of the *Cochran* equation, illustrated in *1a*. This formula is used for large populations (greater than 10.000 subjects) or an unknown total number of subjects [20].

$$n_0 = \frac{Z^2 pq}{e^2} \quad \text{(1a)} \qquad\qquad n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \quad \text{(1b)}$$

In the *Cochran* equation, Z^2 is the critical Z value, found in statistical tables which contain the area under the normal curve (also called *confidence level*), p is the estimated proportion of an attribute that is present in the population, q is *1-p* and, finally, e is the desired level of precision.

On the other hand, if our study requires small population samples (less than 10.000 subjects), we suggest the formula presented in *1b* to estimate the proper number of subjects required in the study [21]. The formula is based on the original *Cochran* equation *1a*, where n is the sample size and N is the population size; and n_0 as sample size can be adjusted using *Cochran* equation *1a*.

In our particular case, in the Polytechnic School "Ing. Jorge Matetu Remus", there are around 200 students enrolled in the telecommunication career. So, the right formula to calculate the most suitable number for the population sample would be the number *1b*.

6 Conclusions

Augmented reality (AR) gradually comes into education boosting systems and applications developed to support educational tasks, fostering the use of AR-based applications by educational staff and students with the aim to enhance parameters of quality in education.

In this paper we describe an approach to enhance learning and teaching through AR-based mLearning technologies. In this approach we have proposed a methodology, where through several stages the different concerns related to the improvement of quality of education are analysed. In addition, as part of the approach and contribution of the paper, a survey to validate user acceptance of AR-based mobile applications has been presented.

We have collaborated with the Polytechnic School "Ing. Jorge Matetu Remus", located in Guadajalara (Mexico) to get the know-how required to propose this approach. As outcome, we have developed *cuceAR*, an AR-based mobile application to provide required functionalities to cover educational needs.

As for future work, we foresee to complete the development of *cuceAR*, develop it for other platforms (*e.g.* iOS) and deploy the entire system to be ready for end-users. Secondly, we will focus in the improvement of the survey to cover usability and usefulness, for instance, adding new questions based on the ISO 9241-11 (Ergonomics of human-system interaction). Finally, we would like to conduct studies in several educational centers, in order to validate our approach.

References

1. Pheeraphan, N.: Enhancement of the 21st century skills for thai higher education by integration of ict in classroom. Procedia-Social and Behavioral Sciences **103**(2013), 365–373 (2013)
2. Gosper, M., Woo, K., Muir, H., Dudley, C., Nakazawa, K.: Selecting ict based solutions for quality learning and sustainable practice. Australasian Journal of Educational Technology **23**(2) (2007)

3. Haddad, W., Jurich, S.: Ict for education: Potential and potency. Technologies for education: Potential, parameters and prospects. UNESCO and Academy for Educational Development pp. 28–40 (2002)
4. Van Krevelen, D., Poelman, R.: A survey of augmented reality technologies, applications and limitations. International journal of virtual reality **9**(2), 1–20 (2010)
5. FitzGerald, E., Ferguson, R., Adams, A., Gaved, M., Mor, Y., Thomas, R.: Augmented reality and mobile learning: the state of the art. International Journal of Mobile and Blended Learning (IJMBL) **5**(4), 43–58 (2013)
6. Sharples, M., Taylor, J., Vavoula, G.: Towards a theory of mobile learning. In: Proceedings of mLearn. vol. 1, pp. 1–9 (2005)
7. Di Serio, Á., Ibáñez, M.B., Kloos, C.D.: Impact of an augmented reality system on students' motivation for a visual art course. Computers & Education **68**, 586–596 (2013)
8. de Educación Pública, S.: Principales cifras del sistema educativo nacional 2016-2017 (2017), https://tinyurl.com/ssvucuf
9. Rodríguez, M.A.G., Arteaga, H.U., Altieri, I.M.S., Ulloa, S.M.H.: Estrategias para disminuir el rezago de reprobación en los programas educativos de la unidad académica de contaduría y administración de la universidad autónoma de nayarit. EDUCATECONCIENCIA **21**(22) (2019)
10. Arcos-Vega, J.L., Marentes, R., et al.: Information and communication technologies (ict) and their relation to academic results indicators in state public universities in mexico. Higher Education Studies **7**(2), 1–6 (2017)
11. Diegmann, P., Schmidt-Kraepelin, M., Eynden, S., Basten, D.: Benefits of augmented reality in educational environments-a systematic literature review. Benefits **3**(6), 1542–1556 (2015)
12. Chao, W.H., Chang, R.C.: Using augmented reality to enhance and engage students in learning mathematics. Advances in Social Sciences Research Journal **5**(12) (2018)
13. Amaya, P.P., Sánchez, J.R., DeMoss, V.G., Carreón, A.M.: Aplicación de realidad aumentada en la enseñanza de la física. Cultura Científica y Tecnológica (51) (2016)
14. Chen, C.H., Chou, Y.Y., Huang, C.Y.: An augmented-reality-based concept map to support mobile learning for science. The Asia-Pacific Education Researcher **25**(4), 567–578 (2016)
15. Erl, T.: Service-oriented architecture: concepts, technology, and design. Pearson Education India (2005)
16. Armbrust, M., Fox, A., Griffith, R., Joseph, A.D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., et al.: A view of cloud computing. Communications of the ACM **53**(4), 50–58 (2010)
17. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly pp. 319–340 (1989)
18. Chang, C.C., Yan, C.F., Tseng, J.S.: Perceived convenience in an extended technology acceptance model: Mobile technology and english learning for college students. Australasian Journal of Educational Technology **28**(5) (2012)
19. Likert, R.: A technique for the measurement of attitudes. Archives of psychology (1932)
20. Cochran, W.: Sampling techniques, new york, 1953. Statistical Surveys E. Grebenik and CA Moser (1963)
21. Israel, G.D.: Determining sample size (1992)