Virtual learning environments for digital electronics using augmented reality

Ambiente virtual de aprendizaje para electrónica digital utilizando realidad aumentada

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Abstract

The 2020 pandemic represents another challenge for universities concerned with guaranteeing Educational Quality and the training of their graduates, which must be in accordance with the demands of the current global labor market. Distance Education, one year after becoming the global resource, has become monotonous and routine for many students. At the same time, augmented reality has become more accessible in many ways and represents a viable option that complements learning environments in a motivating way. Its application in education has been reported with success in various disciplinary areas and its advantages are listed in various investigations. In this work, a methodology for the development of virtual learning environments through augmented reality is reported, which can be developed and applied in any subject of higher education, with which it is presumed that AR can be a tool of general application for the creation of innovative learning objects and environments that improve learning outcomes.

Interactive learning environments, Augmented Reality, Logic Gates

Resumen

La pandemia de 2020 representa un reto más para las universidades preocupadas por garantizar la Calidad Educativa y la formación de sus egresados. La Educación a Distancia, a un año de haberse vuelto el recurso global, se ha tornado monótona y rutinaria para muchos estudiantes. Al mismo tiempo la realidad aumentada se ha vuelto más accesible en muchos sentidos y representa una opción viable que complementa de manera motivadora los entornos de aprendizaje. Su aplicación en la educación se ha reportado con éxito en diversas áreas disciplinares y sus ventajas se enumeran en diversas investigaciones. En este trabajo se reporta metodología de desarrollo de entornos de ambientes de aprendizaje virtuales a través de realidad aumentada, que pueden desarrollarse y aplicarse en cualquier asignatura de educación superior, con lo que se presume que la RA puede ser una herramienta de aplicación generalizada para la creación de objetos y entornos de aprendizaje innovadores que mejoren de los resultados de aprendizaje.

Ambientes de aprendizaje interactivos, Realidad Aumentada, diseño instruccional

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Introduction

Since January 2020, the whole world has been submerged in a pandemic of global levels that has caused dizzying changes in behaviors and behaviors, both individual and social and in dimensions as diverse as care, social coexistence, continuous attention to sanitary measures, work restrictions, mobility restrictions and, of course, in the educational dimension, due to the mandatory restrictions regarding face-to-face attendance in classrooms.

At all academic levels, in an emergent and urgent manner, measures had to be adapted that, to a certain extent, allowed the continuity of academic processes and school cycles.

For universities with four-month periods, such as the Universidad Tecnológica del Norte de Aguascalientes (UTNA), the four-month period from January to April 2021, is already the fourth cycle under this modality of distance education and of a mentioned hybrid education.

Undoubtedly, learning levels have been reduced, so it is urgent to envision measures and strategies that guarantee that students who are graduating from Higher Education Institutions (HEIs) have the minimum competencies that allow them to develop and begin growth. and why not, conclusion of their training, already within companies and the labor field, under whatever line it may be.

That is why, in the universities most committed to this end, innovative didactic strategies have begun to be explored that combat problems parallel to the pandemic and that have emerged, such as the apathy of students for study and learning.

To all this must be added what is mentioned in the study by Cabero Almenara and Fernández Robles (2018), the already tense situation in today's universities caused by globalization, the transformation of new students, internationalization, competition between universities due to the recruitment of students, the vertiginous evolution of knowledge, learning elements, and information technologies, so accelerated, that it seems that there are not enough budgets to be a little up to par.

All this has repercussions in a series of challenges for universities, ranging from new competences that teachers must possess and new competences that must be developed in the curricular contents; but more than anything and initially, the challenge of new instructional designs that are more in line with the new technological scenarios. And according to Álvarez-Arregui & Arreguit (2019), the use of intensive, accessible, versatile and low-cost platforms for management, research, teaching and transfer are progressively acquiring greater relevance due to the added value they generate to processes and the results.

Bueno (1976) points out that all knowledge is based on observation, as a prime and essential starting point. That is why, almost naturally, advances in technology and ubiquitous access to mobile devices have increased the popularity of augmented reality (AR) in recent years. Speaking of today's universities, practically any student has a tablet or a cell phone with a camera and internet access; This facilitates the incorporation of AR in teaching processes without raising costs too much.

Conceptualization of AR

According to Cabero (2016, p. 111), "Augmented reality is characterized by the incorporation of digital information including images, video and audio in the real world. AR aims to mix reality with the virtual, allowing users to interact with both objects, the physical and the digital. " Based on a layer of physical information, digital information is added in different formats (video, image, audio, text ...), thereby causing an increase in information.

The study by Cabero Almenara and Fernández Robles (2018) lists different areas and disciplines where AR has been incorporated for its teaching, some of these are: engineering, architecture, urban planning, medicine, mathematics and geometry, art and history, learning of languages, design, natural sciences, chemistry and physics, geography; It also specifies that the educational level where the highest and best results are being achieved is higher education.

This same author identifies different advantages and possibilities of the application of augmented reality, to mention a few: i) the information is enriched, including that already printed, to make it more understandable to the student, ii) the object can be observed from different points of view. view, iii) it can be used at different educational levels and in a diversity of subjects, iv) ubiquitous learning and active learning are promoted, v) the training scenarios are really motivating, vi) it is capable of encouraging students to become in producers of other learning objects with which they can improve divergent processing.

According to Cabero et al. (2019), the most enriching situations for learning are those where the student must experiment, analyze, test the initial conception of it and can also provide clues and suggestions; and that the levels of student satisfaction after AR experiences do not depend on the level of studies or on the specific curricular content in question. This last conclusion agrees with those of the study by Fombona et al. (2017).

Background

The application of AR within learning environments is an innovative way to apply new technologies in educational settings from basic level to higher education, continuously seeking to generate greater interest on the part of students by motivating them to acquire knowledge through means that are different from the traditional ones. In addition, it should be mentioned that AR, with respect to virtual reality (VR), is considered with a broader level of application, because it integrates digital elements within the real world (Martínez García & Dalgo Flores, 2018); It should also be mentioned that with AR the student remains in the real world and does not lose contextualization.

The study by Estapa, A. & Nadolny, L. (2015) showed that AR improved students' motivation towards learning mathematics; applied the possibility of observing videos, web pages, audios and different images that were added through AR to printed documents.

The study by Lobo Quintero, et al (2019) reports the use of the Unity 3D program in conjunction with the Vuforia SDK (software development kit) for the development of a learning system focused on teaching basic science courses in the Autonomous University of Bucaramanga - UNAB.

Justification

Many of the articles on this topic mention theories, conceptualizations, different proposals and even the potential advantages that the application of AR in learning environments would bring. Others point out the feasibility of its application and the specific possibilities of use; but not many of the articles show specific results of its application, therefore the justification for this work comes from the fact that this proposal for a virtual learning environment will enable, in future work, the specific application in a subject that is currently taught at the UTNA.

Cabero Almenara & Fernández Robles (2018) highlight, as one of the disadvantages of AR, the lack of educational materials; Through this work, a reproducible methodology is presented with which a large number of learning objects can be carried out, applicable in practically any subject without involving significant work for the teacher.

AR is a technology that must continue to be experienced and applied directly in the classroom because the research by Tekedere & Göker (2016), which analyzed results from 2005 to 2015, the effect of applying AR to education is 0.677, which implies a positive effect that should continue to be exploited.

On the other hand, Fombona et al. (2017) carried out an exhaustive review of the scientific literature up to 2016 in the Web of Science (WOS) about RA and found the results shown in Table 1. The same author reports the numbers of articles with the term RA distributed by the main subject areas in Table 2.

Theme	Used as theme	As part of the title
Augmented reality	10,155 ref.	4,262 ref.

Table 1 RA references in WOS until 2016
Source: Fombona, (2017)

AR in the subject área	As theme	As part of the title
Social Sciences	755	319
Technological Science	1888	811
Computing and engineering	1694	726
Physical sciences	302	174
Biomedicine	464	105
Arts and Humanities	158	66

Table 2 RA references in WOS up to 2016 by subject area
Source: Fombona, (2017)

The previous data show that the application of AR has increased in recent years, as reported by Ruiz Cerrillo (2020), the application in education has not been homogeneous in terms of methodology, approach, or instrumentation. This work can provide a homogeneous methodology to the teachers of the UTNA.

The central hypothesis is that it is possible to develop an AR-based learning environment for the introductory topic on digital logic gates.

The main objective of this work is to develop an interactive learning object, specific for the topic of Introduction to digital logic gates of the Mechatronics Engineering career at UTNA.

Method

Due to the fact that at the higher level the highest dropout percentages are located in the first semesters or semesters, one of the first specialty subjects was selected for Mechatronics Engineering students at UTNA.

The specific topic of digital logic gates was chosen because this topic is of great relevance because it is the basis of another diversity of topics of industrial application such as counters, ladder logic, embedded systems and microcontrollers and that together make up one of the great branches for mechatronic engineers: digital electronics. An additional advantage of selecting one of your first specialty subjects is that it can motivate students to enter additional programming languages on their own, which would provide them with very relevant tools for the development of their professional careers.

Lobo Quintero, et al (2019) mentions that three elements are essential in any learning environment: learning strategies, learning technologies and a pedagogical model.

In this work, the learning strategy is to support multiple perspectives of the student, through presenting information in different ways to the student so that they can create connections and also their own explanations, acquiring flexible and meaningful knowledge structures. The learning technology is the AR that will be developed using a Merge Cube® (Figure 1) and will be programmed on the CoSpaces® platform (Figure 2). The pedagogical model is that of augmented learning, proposed by Klopfer in Ketelhut, D. J. (2009) and which is defined because the learning environment adapts to the needs and inputs available to students.

Figure 1 Original Merge Cube. [Photography]. (2020)
Source: <https://www.adorama.com/merarc01.html>

Figure 2 CoSpaces platform on the computer
Source: <https://edu.cospaces.io/Studio/Spaces>

Development

For the production phase of learning technologies, the following stages were developed:

- The specific content of the topic for which the learning object was developed was determined.
- The visual elements that could contribute the most to meaningful learning were identified and created; made sure they all had a high resolution.
- The distribution of the elements present in the merge cube was planned, according to the learning sequence, defined in the digital electronics course sheet, where the topics of: description of the gates, symbologies, truth tables and Boolean functions.
- Multimedia content was located to complement the learning experience, in this case it was a review video tutorial and an online simulator.
- A free teacher account was created on the CoSpaces® platform and a test access was managed that would allow the use of the Merge Cube® addon.
- A Merge Cube (R) was assembled from the printable version of it (Figure 3); to give a little more physical robustness, it was printed on matt opaline paper with a laser printer. Practically this would be the only investment on the part of the students.
- All the elements were uploaded to the platform: images, texts and multimedia files.
- It was created that created a main stage to welcome the student and to navigate through the different gates; As part of this main scenario, access to a padlet was placed, which in this case is the tool that will allow the student to interact with other classmates, while recording their learning in a dynamic and free way.
- A separate stage was created for each gate. This scenario is composed as follows: i) a very brief textual introduction accompanied by the gate symbol, ii) the gate truth Table, iii) the gate configuration in a real integrated circuit, as well as a photo of it, iv) an access to the video tutorial, v) the link for the online simulator and vi) a button to return to the main stage.
- A program was made for each scenario using block logic in CoSpaces®. The main stage program allows navigation to each of the seven gates as well as access to the padlet for recording learning. The program of the scenarios of each gate allows a fluid movement of the elements as well as what shows certain messages that provide a sensation of greater interaction.
- Finally, the CoSpace created, was shared in the platform's own cloud and the code and QR were generated for free access.

Figure 3 Merge Cube printable

Source: <https://www.mergevr.com>

Results

Figure 4 shows the CoSpaces® layout for the main stage. To access each of the gates and their specific content, on the screen of the cell phone or tablet, you must press the corresponding button. To access the created padlet, click on its logo and a balloon will be displayed indicating the access link, which was simplified through a personalized shortener. The student must enter the address on the device from which they want to navigate, since the current version of CoSpaces® does not allow direct linking to internet links or other web commands.

Figure 4 CoSpaces® design of the main stage
Source: Own elaboration

In Figure 5 the main scenario is shown as RA on the screen of a cell phone where the CoSpaces Edu application was previously installed. This application is free and can be installed on cell phones or tablets with Android or IOS operating system, does not require registration, does not include shopping offers and the only requirement is that the device where it is installed has a rear camera (Figure 6).

Figure 5 RA of the main stage observed through a cell phone
Source: authors

Figure 6 Screenshot of the CoSpaces application running on a Xiaomi cell phone
Source: Own elaboration

Figure 7 shows the distribution of the elements that make up the stage for each logic gate and their location on the faces of the Merge Cube®. When the graphic elements were integrated into the cube, they were located in such a way that they are part of it, but are separated from their surfaces and edges; this was done in order to increase the sensation of the AR to the user.

Figure 8 shows the program developed for one of the gates, in this case for the OR gate. Elements were integrated that increase the possibility of user interaction with AR, to increase motivation.

Figure 7 Merge Cube printable layout
Source: Own elaboration

In Figure 9 the QR code is presented, which in turn integrates the alphanumeric code to access, from the CoSpaces Edu application, the learning scenario created.

Figure 9 QR and alphanumeric code to access the created learning scenario
Source: Own elaboration

Finally, in Figure 9 and Figure 10 the completed and fully functional learning scenario is presented; the execution of the AR can be observed through the screen of the cell phone where the test was done.

Figure 8 Program for the OR gate made in CoSpaces®
Source: Own elaboration

Figure 10 RA of the main stage observed through a cell phone
Source: Own elaboration

Figure 11 AR of the tutorial video observed from a cell phone screen
Source: Own elaboration

Conclusions

The use of learning environments with AR in the first subjects of Digital Electronics, can accelerate the achievement of learning results and allow more advanced results at the end of the course.

With the constant advancement and development of AR content creation tools and technologies, coupled with the fact that these are increasingly being made available to society in general for free, it is presumed that AR can be a tool of widespread application for creating innovative learning objects and environments.

The use of the CoSpaces® platform allows the integration of multifunctions in the objects used, thanks to its integrated programming tools, which increases the possibilities and options of interaction in the learning environments with AR created from this platform.

Future job proposal

Train the UTNA faculty to apply the proposed methodology in the development of learning objects for their particular subjects.

Generate a free repository where the learning objects produced can be accessed, enriched and reused by all teachers. This repository would require basic information such as the description of the object, career and subject to which it belongs, explanatory video of the operation of the object, app required for its use, accompanying or complementary material, as well as contact with teachers who have worked in each object. This repository can be extended to several State Universities.

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Annexes

League for Printable Merge Cube:
<https://mergeedu.com/download/file.php?f=paper-merge-cube.pdf>

References

- Álvarez-Arregui, E., & Arreguit, X. (2019). El futuro de la Universidad y la Universidad del Futuro. Ecosistemas de formación continua para una sociedad de aprendizaje y enseñanza sostenible y responsable. *Aula Abierta*, 48(4), 447–480.
<https://doi.org/10.17811/rifie.48.4.2019.447-480>
- Barroso Osuna, J., & Gallego Pérez, O. (2016). La realidad aumentada y su aplicación en la educación superior. *Revista del Salomé*, 1(2), 111–124.
https://www.academia.edu/38206852/La_realidad_aumentada_y_su_aplicacion_en_la_educacion_superior
- Bueno, G. et al. (1976). Estatuto Gnoseológico de las ciencias humanas. Fundación Juan March, programa Filosofía. Oviedo, Esp. Recuperado de <http://www.fgbueno.es/med/dig/egch0192.pdf>
- Cabero, J., García-Jiménez, F., & Barroso, J. (2016). La producción de objetos de aprendizaje en Realidad Aumentada: la experiencia del SAV de la Universidad de Sevilla. *International Journal of Educational Research and Innovation (IJERI)*, 6, 110-123
 ISSN: 2386-4303
- Cabero Almenara, J., & Fernández Robles, B. (2018). Las tecnologías digitales emergentes entran en la Universidad: RA y RV. *RIED. Revista Iberoamericana de Educación a Distancia*, 21(2), 119.
<https://doi.org/10.5944/ried.21.2.20094>
- Cabero, J., Barroso, J., & Llorente, C. (2019). La realidad aumentada en la enseñanza universitaria. *REDU. Revista de Docencia Universitaria*, 17(1), 105.
<https://doi.org/10.4995/redu.2019.11256>
- Estapa, A. & Nadolny, L. (2015). The Effect of an Augmented Reality Enhanced Mathematics Lesson on Student Achievement and Motivation. *Journal of STEM Education*, 16(3). Laboratory for Innovative Technology in Engineering Education (LITEE). Retrieved April 15, 2021 from <https://www.learntechlib.org/p/151963/>.

Fombona, J., Pascual-Sevillano, M. D. L. N., & González-Videgaray, M. (2017). M-learning and augmented reality: A review of the scientific literature on the WoS repository. *Comunicar*, 25(52), 63–72. <https://doi.org/10.3916/c52-2017-06>

Ketelhut, D. J. (2009). Eric Klopfer: Augmented Learning: Research and Design of Mobile Educational Games. *Journal of Science Education and Technology*, 19(2), 212–214. <https://doi.org/10.1007/s10956-009-9184-0>

Lobo Quintero, R.A., (2019) Santoyo Díaz, J.S. & Briceño-Pineda, W., EducAR: uso de la realidad aumentada para el aprendizaje de ciencias básicas en ambientes educativos y colaborativos. *Educación en Ingeniería*, 14(27), 65-71

Martínez García, D. N., & Dalgo Flores, V. M. (2018). Ambientes virtuales de aprendizaje utilizando realidad aumentada. *Enfermería Investiga: Investigación, Vinculación, Docencia y Gestión*, 3(1, Mar), 49–52. <https://doi.org/10.29033/ei.v3n1.2018.10>

Ruiz Cerrillo, S. (2020). Augmented reality and learning in organic chemistry. *Apertura*, 12(1), 106–117. <https://doi.org/10.32870/ap.v12n1.1853>

Tekedere, H. & Göker, H. (2016). Examining the Effectiveness of Augmented Reality Applications in Education: A Meta-Analysis. *International Journal of Environmental & Science Education*, 11(16), 9469-9481.