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The transcendence of Augmented Reality in student motivation. A systematic review and meta-analysis

La trascendencia de la Realidad Aumentada en la motivación estudiantil. Una revisión sistemática y meta-análisis

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Abstract

The arrival of information and communication technologies (ICTs) in the education system has meant that many new resources of great didactic interest have reached the classroom. This is the case of Augmented Reality, a technology that has become popular due to its ability to combine virtual and real elements at the same time. This work has attempted to investigate the scientific literature to see if the application of Augmented Reality in the classroom promotes a motivational improvement in the student body of the various educational stages. For this purpose, the methodology corresponding to the systematic reviews and meta-analysis proposed by the PRISMA declaration was used, taking as data source the databases Scopus and Web of Science. A total of nine quasi-experimental methodologies were analysed around the measurement of the motivation variable. The results elucidated a favourable diagnosis to the experimental groups, so it could be inferred that experimentation in the classroom with Augmented Reality motivates the student body of different educational stages. Nevertheless, it is necessary to carry out a greater number of experiences with Augmented Reality in the classrooms in order to be able to establish an opinion around a more solid body of scientific work.

Keywords: Augmented Reality, motivation, emerging technologies, systematic review, meta-analysis, education.

Resumen

La llegada de las tecnologías de la información y comunicación (TIC) al sistema educativo ha propiciado que numerosos recursos novedosos y de gran interés didáctico lleguen a las aulas. Este es el caso de la Realidad Aumentada, tecnología que se ha popularizado por su capacidad para combinar elementos virtuales y reales al mismo tiempo. El presente trabajo ha pretendido indagar en la literatura científica para comprobar si la aplicación de Realidad Aumentada en las aulas promueve una mejora motivacional en el estudiantado de las diversas etapas educativas. Para ello, se recurrió a la metodología correspondiente a las revisiones sistemáticas y meta-análisis propuestas por la declaración PRISMA tomando como fuente de datos las bases de datos Scopus y Web of Science. Un total de nueve de metodología cuasi experimental fueron analizados en torno a la medición de la variable motivación. Los resultados dilucidaron un diagnóstico favorable a los grupos de carácter experimental, por lo que se pudo inferir que la experimentación en el aula con Realidad Aumentada motiva al estudiantado de distintas etapas educativas. No obstante, se plantea la necesidad de realizar mayor número de experiencias con Realidad Aumentada en las aulas para poder establecer un dictamen en torno a un cuerpo más sólido de trabajos científicos.

Descriptores: Realidad Aumentada, motivación, tecnologías emergentes, revisión sistemática, meta-análisis, educación.

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1. Introduction and state-of-the-art

Society has undergone profound transformations in recent years, impacting not only the social level, but also the educational. The advent of information and communication technologies (ICT) has led the educational process to turn the direction towards active learning and innovation (Ravelo, Revuelta, & González, 2018). Faced with these changes, educational institutions need to reconsider the educational priorities that are aimed at the conception of education, and that their pedagogical approaches have a holistic and current vision that involves cognitive, procedural and attitudinal aspects, which train people with functional skills and competencies in, with and for digital media (Trujillo, Aznar, & Cáceres, 2015; Esteve, Adell, & Gisbert, 2013; De Pablos, Bravo, & Moreno, 2010).

In this sense, with the advent of ICTs in the educational context, numerous technological resources started being used in the classrooms, with the aim of energizing the teaching-learning process through the active learning of students supported by these tools. It is a school context where students now do not learn as before, and therefore the mission of the education system is to find the resources that allow students to approach content in an attractive and novel way (Hinojo, Aznar, Cáceres, & Romero, 2019).

Among these resources, Augmented Reality is now a technology that has been introduced in most sectors of society including education. Although its use began in the early 1990s (Caudell & Mizell, 1992), it has now become popular due to the cheapening of its use and simplification in the equipment and devices necessary for its use (Akçayır & Akçayır, 2017). In this way, this technology is being the subject of research in various sectors (Chicchi-Giglioli, Pallavicini, Pedroli, Serino, & Riva, 2015), among which is education due to the application of Augmented Reality in the different stages and areas.

As this is a relatively recent concept, an approximation to its definition is necessary for the correct understanding of it. Thus, since the late 20th century authors such as Azuma (1997) has defined Augmented Reality as a technology that improves the sensory perception of the user, superimposing virtual objects to the real world, thus seeming that these virtual elements belong and coexist in the same space as real objects.

The concept of Augmented Reality may get confused with another term that it is related with, which is Virtual Reality (Gómez-García, Rodríguez-Jiménez & Ramos, 2019). Both terms refer to different levels of user immersion in virtual environments where the real and the virtual coexist (Di Serio, Ibáñez & Delgado, 2013). The main difference that distinguishes both technologies would be that while Augmented Reality combines virtual elements in real environments or contexts, Virtual Reality completely replaces a real environment with a virtual one. Therefore, when researching the subject and implementing it in the educational context, it is important to distinguish between the two concepts.

Today, professors and the educational community benefits from the possibilities offered by technology, reason for which knowing the potential of Augmented Reality applied to education at all levels is necessary. Thus, various authors (Kellems, Cacciatore, & Osborne 2019; Park, Ro, Lee, & Han, 2018; Akçayır & Akçayır, 2017; Cabero & García, 2016) have presented the advantages of Augmented Reality:

- It helps speakers participate in real-world experiences and explorations
- It makes it easier to perceive events or circumstances that are more complicated without Augmented Reality
- It increases the motivation and satisfaction of students
- It helps acquire research skills
- It creates learning environments where the combination of real and virtual elements prevails
- It encourages and develops critical thinking and problem-solving capacity

- It promotes communication through collaborative tasks
- It increases positive attitudes towards the subject being taught (Akçayır, Akçayır, Pektas & Ocak, 2016).

Likewise, the limitations of Augmented Reality (Muñoz-Cristóbal *et al*., 2015) have been specified in the scientific literature:

- Difficulties and technical problems during its use
- A correct and detailed user guide is required so that it is not too complicated for students
- A large amount of pre-reading is essential for its proper use (Muñoz-Cristóbal *et al*., 2015).

It is well known that technologies, in most cases, provide a number of benefits to students for the novelty of introducing them to the classroom. These benefits are not only at the level of development and facilitation of teaching-learning processes, but also at the level of the individual aspects of personal development. In this regard, motivation is placed as an element that all these new trends aim to increase and enhance to the highest levels (Hernández-Horta, Monroy-Reza & Jiménez-García, 2018; Ortiz-Colón, Jordán & Aredal, 2018), because this increase results in other positive consequences, such as higher levels of involvement, greater interest in the subject or topic, etc. (Fuentes, López, & Pozo, 2019; Quintero Jiménez & Area, 2018).

In addition, research carried out such as that of Di Serio *et al.* (2013) demonstrate how the use of Augmented Reality implies an increase in motivation that reverts to higher levels of personal satisfaction of the students and greater attention, as long as the themes are of their interest. Additionally, studies conducted on students of Higher Education affirm that the application of Augmented Reality promotes a motivational improvement, not only to future teachers, but to future professionals from different disciplines, showing the global nature of Augmented Reality (Cabero & Roig, 2019; Tzima, Styliaras, & Bassounas, 2019; Fuchsova, & Korenova, 2019).

On the other hand, it should be noted that in recent times it is necessary to research previous studies on a particular topic before addressing it; thus, the current state of the subject is checked and the different lines of research can be established to be followed or explored. This is what is generally intended for a systematic review, and it is the aim of this study. Currently, there are several documents of the scientific literature that carry out a systematic review and address technology in general and its involvement in education (Cant & Cooper, 2010; Habler, Major & Hennessy, 2016; Rodríguez-García, Raso & Ruiz, 2019), and in a specific way, although to a lesser extent Augmented Reality (Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014), as well as other trends involving the use of technological devices (Pimmer, Mateescu & Gröhbiel, 2016). Also, there are systematic studies linked to Augmented Reality: on the one hand, the work of Pellas, Fotaris, Kazanidis and Wells (2019) focused on their presence in the game, stating that its application influences the primary and secondary education students' cognitive skills. In short, there is the study of Quintero, Baldiris and Rubira (2019) in which it was visualized that the use of Augmented Reality favored the inclusion of those students who had visual, motor, cognitive and hearing difficulties, showing an increase in motivation and improved performance.

2. Methodology

Based on the ideas mentioned above, the aim of this paper is to complete the following: a) find documents of impact and prestige that have experienced Augmented Reality in the educational field; b) analyze the transcendence of Augmented Reality in student´s motivation. These are the research questions based on the above:

RQ1: How many studies were published in the last 5 years?

RQ2: Who are the most recognized authors in the field of Augmented Reality?

RQ3: In what areas or disciplines of knowledge are these studies most published?

RQ4: Does the Augmented Reality app significantly influence student´s motivation?

This work has followed the methodological guidelines for systematic literature review to answer these questions (Rubio-Aparicio, Sánchez-Meca, Marín & López, 2018; Okoli & Schabram, 2010). For its elaboration, the quality standards of the PRISMA declaration for systematic reviews were taken into account (Urrutia & Bonfill, 2010), as well as impact works that follow this type of methodology (Hinojo, Aznar, Cáceres, Trujillo, & Romero, 2019).

Figure 1. Synthesis of the steps to be taken in the systematic review with meta-analysis (PRISMA Declaration)

Own elaboration

2.1. Search strategy

To ensure the sensitivity of the search process, the search equation used in the database was applied as follows: "Augmented reality" and "Motivation" and "Education". For not limiting the number of results, no particular educational stage was included as a descriptor.

The data search was set in the Web of Sciences (WOS) and Scopus database in the Eselvier group. These are the most scientifically prestigious database in JCR and SJR impact index, respectively. In the case of the Web of Sciences, the search was carried out on the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCIE) and Arts and Humanities Citation Index (AHCI).

2.2. Procedure

The method carried out for obtaining the sample was divided into three phases from the inclusion and exclusion statement criteria which allowed the initial number of documents to be limited (Table 1). Impact journal articles were used for open access, so that they could be investigated in detail. Subsequently, it was specified in that recent productivity with the aim of establishing an updated opinion.

In addition, those studies of quasi-experimental methodology were taken into account, so that, in the subsequent meta-analysis, a comparison of the work favorable to the control or experimental group could be established. Following this idea, those articles were chosen in which the motivation variable was measured, and, in turn, it was avoided to analyze the case studies, so a criterion regarding the minimum sample size was implemented.

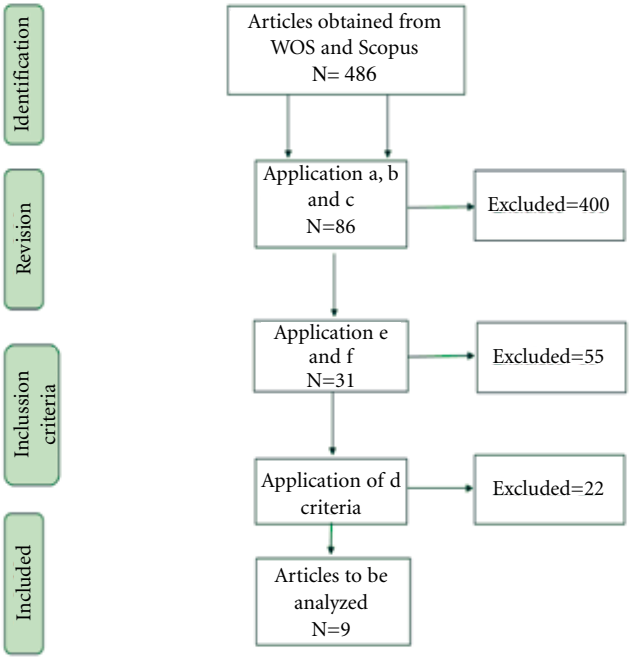
Table 1. Inclusion and exclusion criteria

Criterios de inclusión	Criterios de exclusión
a) Journal Articles b) Publications in the last five years (2014-2019) c) Open-Access d) Studies involving control and experimental group treatment e) The builder to measure is motivation. f) The sample size in the pos-test must be greater than four participants	a) Proceedings of Congresses, Book Chapters, Book or others... b) Restricted Access to the publication c) Motivation is not specified as study construct d) Theoretical studies or revisions e) Duplicate articles

Own elaboration

The flowchart shows the process followed, the scientific articles found, and the formation of the final sample (Figure 2).

Figure 2. Flowchart as stated in the PRISMA statement



Own elaboration

2.3. Data Analysis

Data analysis has been performed through Review Manager v.5.3 software. First, the initial sample that was subjected to a refinement process was formed until the final sample was obtained at the end of phase 3. Each of the documents that constitutes it has been examined through a content analysis (Urrutia & Bonfill, 2010).

3. Results

Once the sample is counted, a total of 9 documents were obtained as the final sample of the systematic review. A forest plot was established, tak-

ing into account measures of a descriptive nature (mean and standard deviation) that allowed to establish a final opinion on the significance of using augmented reality in student´s motivation.

3.1. Systematic review

The studies analyzed were grouped according to the year of publication. It should be noted that most of these have been published in 2019, excepting two works (Gutiérrez & Fernández, 2014; Toledo-Morales, & Sánchez-García, 2017) in 2017 and one in 2014.

On the other hand, most articles are written by various authors (Table 2). The application of augmented reality is independent of any discipline, thus studies are found in different disciplines, such as engineering, computer science, medicine or education.

Table 2. Authors of the studies and their number of publications

Author	Total of studies
Lai, A., Chen, C., Gutiérrez, J.M, Fernández, M.D., Toledo-Morales, P., Sánchez-García, J., Liu, Y., Lu, S., Kao, C., Chung, L., Tan, K., Henssen, J.A., van den Heuvel, L., De Jong, G., Vorstenbosch, A., van Cappellen, V., Van den Hurk, M., Kooloos, G., Bartels, H., Kirikkaya, E., Basgul, M., López- Belmonte, J., Pozo, S., Belmonte, G.L., Ibáñez, M.B., Peláez, J., Kloos, C., Wang, Y.	1

Own elaboration

Taking into account the journals that publish scientific work (table 3), it is observed that the works have been published in different countries, and therefore in different languages. From the nine documents analyzed, it is noted that only more than one of the scientific papers are found in the United Kingdom. As for h-index, there are varied coefficients, especially that of the Journal of Computer Assisted Learning and the British Journal of Educational Technology.

Table 3. Publication countries of the Journals and their h-index

References	Journal	Country	h-Index
Lai *et al.* (2019)	British Journal of Educational Technology	United Kingdom	73
Gutiérrez and Fernández (2014)	International Journal of Engineering Education	Ireland	35
Toledo-Morales and Sánchez (2017)	Revista Latinoamericana De Tecnología Educativa-Relatec	Spain	9
Liu *et al.* (2019)	International Journal of Engineering Business Management	Croatia	13
Henssen *et al.* (2019)	Anatomical sciences education	USA	41
Kirikkaya and Basgul (2019)	Journal of Baltic Science Education	Lithuania	12
López-Belmonte *et al.* (2019)	Pixel-Bit, Revista de Medios y Educación	Spain	6
Ibáñez et al. (2019)	Advances in Intelligent Systems and Computing	Germany	12
Wang (2017)	Journal of Computer Assisted Learning	United Kingdom	74

Own elaboration

In terms of the characteristics of the samples analyzed in the studies collected (Table 4), most studies have applied Augmented Reality in university students (Higher Education), although studies are also found at the Primary and Children's Education.

Table 4. Research and educational stage of the studies

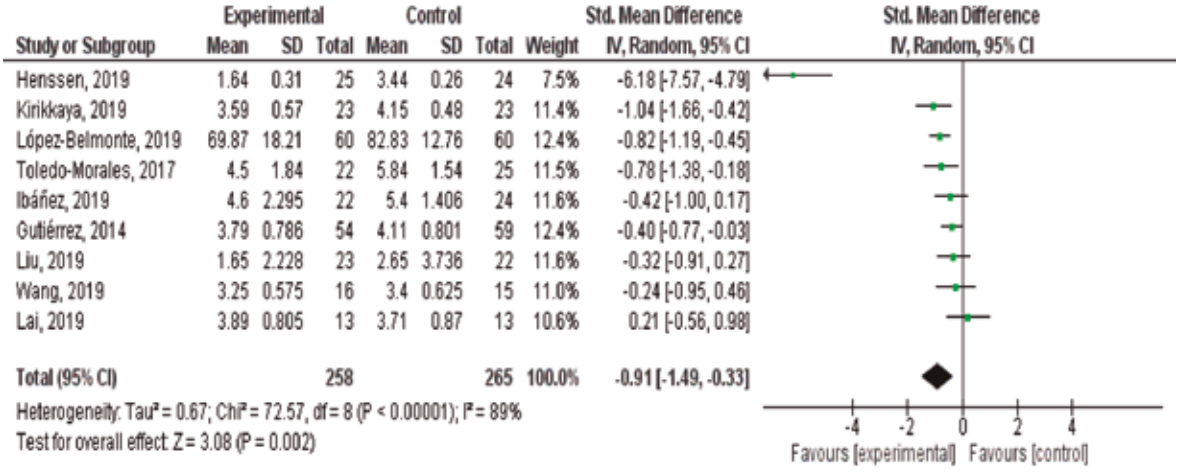
Reference	Educative phase		
	Pre-school	High school	Higher education
Lai *et al.* (2019)			
Gutiérrez y Fernández (2014)			X
Toledo-Morales y Sánchez (2017)		X	
Liu *et al.* (2019)			X
Henssen *et al.* (2019)			X
Kirikkaya y Basgul (2019)		X	
López-Belmonte *et al.* (2019)	X		
Ibáñez *et al.* (2019)			X
Wang (2017)			X

Own elaboration

3.2. Meta-analysis

Meta-analysis was developed through continuous data from the nine scientific papers collected (Henssen *et al.,* 2019; Kirikkaya & Basgul, 2019; López-Belmonte *et al.,* 2019; Ibáñez *et al.,* 2019; Liu *et al.,* 2019; Wang, 2017; Lai *et al.,* 2019; Toledo-Morales *et al.,* 2017; Gutiérrez & Fernández, 2014). First, it is important to note that the statistical weight of each document analyzed is very similar. Based on the elaborate forest plot, it is shown that the results are generally favorable to the experimental group. Specifically, it is noted that a big part of the work has lower means and a lower degree of dispersion, reflecting a higher degree of agreement on the part of the students analyzed stating that the application of Augmented Reality was positive. Among the studies analyzed, the research of López-Belmonte *et al.* (2019) stands out. (2019) in which a considerable improvement is experienced once Augmented Reality was applied in the experience. Only an unfavorable result was found in the improvement of the motivational level following the experimentation of Augmented Reality (Lai, 2018).

Figure 3. Meta-analysis forest plot with continuous data



Own elaboration

Discussion and conclusions

The application of Augmented Reality is a study trend to be considered in education. The results of the systematic review carried out have allowed to observe its application in the different educational stages. First, it is a subject whose experimentation in the classroom is booming as shown by the diachronic production of the articles examined, which mostly belonged to this year 2019. Referring to the authors, this study has determined that there are numerous authors who have published at least one scientific paper on Augmented Reality. This idea indicated that there are no specialized authors in the area.

However, this is a novel theme at a global level as shown by the analysis of the different journals in which the articles on Augmented Reality have been published. From the nine documents, a total of five different countries of origin have been distinguished. They are mostly journals related to Technological Education and teaching innovation, but the provenance of the articles is varied: from the engineering branch to the medical branch and finally, in greater number education.

On the other hand, the results of this work allowed to infer on the idea that the application of Augmented Reality in the classrooms of different educational stages promotes an improvement in student´s motivation. This result becomes the line of other similar studies on the motivational increase through the application of emerging technologies (Rodríguez-García, Raso & Ruiz, 2019; Pimmer, Mateescu & Gröhbiel, 2016). Although the heterogeneity of the model is not complete, the significance of the model is optimal, and has allowed to establish an optimal approach to the idea intended to infer with the approach of this work: the application of Augmented Reality in the classrooms causes a motivational improvement in the student. This results agree with the results expressed in previous researches (Cabero & Roig, 2019; Tzima, Styliaras & Bassounas, 2019). In the same way, the inference obtained from this study also relates to the results of the systematic reviews referred to above, adding consistency to the argument that this work intends to provide (Pellas, Fotaris, Kazanidis & Wells, 2019; Quintero, Baldiris, Rubira, Cerón & Vélez, 2019).

In short, Augmented Reality is an emerging resource that can constitute a motivational improvement in the student. Additionally, it is a current way to be used for the teaching-learning process in the classrooms at any stage (Di Serio *et al*., 2013).

Finally, regarding the limitations of the study, they are mainly directed towards the sample size. As these studies follow a quasi-experimental methodology in different classrooms, the set of subjects analyzed in the nine scientific articles is not numerous. Therefore, as a future line of research, it is proposed to continue applying Augmented Reality at different educational stages, and to continue checking the motivation progress once the resource has been applied, in order to create a set of scientific articles that can corroborate the lines established by the model created in this work.

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