A Systematic Literature Review of Augmented Reality in Engineering Education: Hardware, Software, Student Motivation & Development Recommendations.

Mauricio Vásquez-Carbonell
mvasquez1@cuc.edu.co
Universidad de la Costa, Colombia

Abstract

Augmented Reality (AR) is a technology that has benefited from the massification of computational devices, putting it in the focus of researchers as a novel teaching aid in engineering. For this very reason, a great amount of information about AR in engineering education is emerging constantly. To synthesize the information, a Systematic Literature Review (SLR) was carried out and 4 research questions were raised. It was found out the researcher´s trend for the development and testing of software that takes advantage of AR for engineering students. It was also found that Germany and India are the leading nations on investigations about the investigated topic. On the software side, Unity is the most used tool for creating applications and that the target hardware is smartphone. Finally, the high interest of researchers to increase motivation in students is evidenced in this SLR and recommendations were made based on the researcher's findings.

Keywords

Augmented Reality; Engineering Education; Student Motivation; Development recommendations.

I. Introduction

Augmented Reality (AR), along with Virtual Reality (VR) and Mixed Reality (MR) are technologies that provide new ways to accomplish the Teacher-Student knowledge transfer process (Grodotzki, Ortelt & Tekkaya 2018). Focusing on AR, it is appropriate to confirm that it has benefited from the different common-daily technologies, creating a change in the perception of what formal education/ training can be (Akçayır & Akçayır 2017; Karakus, Ersozlu & Clark 2019; Zhu, Cao & Cai 2020). Large companies have also noticed the trend to use AR and have developed multiple projects to promote its use, as well as produced hardware (such as Microsoft with HoloLens) and software (such as Google with ARCore) that are widely available for use (Mylonas, Triantafyllis & Amaxilatis 2019).

There are many successful cases that support the aforementioned, for example, the use of AR together with books to teach electromagnetism to children in schools, which has proven to be beneficial for those students who have problems in this subject using traditional methods (Billinghurst & Dünser 2012), the use of AR to provide real-time information to surgeons, both new and expert, in order to identify the area to operate and obtain real-time feedback on their performance (Fourman et al. 2021) and the use of projectors, audio AR and see-through glasses in order to create an interactive environment and thus, encouraging a user to improve their physical skills (Soltani & Morice 2020). AR shows benefits for retention of knowledge, as well as the understanding of the complicated topics, better performance of physical activities, an increased willingness to collaborative work, reduction in the distraction of students and a more efficient learning process (Radu 2014; Billinghurst & Dünser 2012). These benefits can be seen in Table 1.

The principle of AR consists in the union of virtual three-dimensional objects like texts and images with the real world (Reyes-Aviles & Aviles-Cruz 2018). These elements are created using specific software (Opriş et al. 2018), such as Unity (Liu et al. 2019) and Vuforia (Bakkiyaraj et al. 2020), to later be displayed using specialized hardware like AR glasses (Bologna et al. 2020) and smartphones (Mylonas, Triantafyllis & Amaxilatis 2019), with the purpose of providing a user with greater knowledge of their environment. This technology has been improving over time, which drew the attention of professionals from all areas, including teachers and students in engineering that have found educational benefits in the use of AR (Wang, Ong & Nee 2018).

Those actors have profited from the creation of new didactics methods that has provided support in multiple situations, including those unanticipated caused by the SARS-CoV-2 virus (Grodotzki, Upadhya & Tekkaya 2021; Grodotzki, Ortelt & Tekkaya 2018). AR takes advantage of the massification of multiple technologies, such as smartphones, laptops, Personal Digital Assistant (PDA), Smartwatches and tablets, among many others (Antonioli, Blake & Sparks 2014), highlighting the contribution of glasses and smart mobile phones (Prendes Espinosa 2014).

The objective of this work is to present a synthesis of the most recent information of AR on engineering education focusing on 1) The topic of the studies 2) Origin of those studies 3) Most used software to program in AR and 4) Most used hardware in those studies. To achieve this, a Systematic Literature Review was carried out to find research trends in the 4 mentioned topics.

Also, the approach that researchers have given to their research on AR in education will be examined and finally, a series of recommendations will be provided based on the studies analyzed.

Benefits of AR in Education
- Retention of Knowledge
- Better understanding of different subjects
- Better performance of physical activities
- Increasing in collaboration
- Reduction in distraction
- Efficiency in the learning process

Table 1. Benefits of AR in Education according to (Radu 2014; Billinghurst & Dünser 2012)

II. Augmented Reality and differences with Virtual Reality and Mixed Reality

The first physical element in the field of VR and AR date back to 1960, when Morton Heilig created the called Sensoramas. These devices played movies for a viewer, while stimulating the senses of the user by different means; generation of odors, smoke and vibrations (Heilig 1992). This represented the first step towards building a device that could alter the reality of a person. The next step was made by Ivan E Sutherland in 1960´s, when he proposed the principles of virtual reality in a work called "The Ultimate Display" (Sutherland 1965). He then proceeded to create a device called "The Sword of Damocles", which was a kind of Head-Mounted Display (HMD), that a user wore on their head (Sutherland 1968) with the intention of experiencing a synthetic world created by computers (Vásquez Carbonell & Silva-Ortega 2020). The developments in virtual reality were continuous and increasingly detailed scenarios were created with the intention to give the user a better immersion and the ultimate goal that a user cannot distinguish a virtual world from a real one (Sutherland 1965; Sanchez-Vives & Slater 2005; Fuchs et al. 1992; Slater 2009).

In 1990 Thomas P. Caudell a worker at Boing Computer Services, Research and Technology coined the term “Augmented Reality” (Lee 2012; Garzón & Acevedo 2019) to refer to a variant of VR (Azuma 1997), where it is not sought to make the user believe that he is in a different place than his physical body is, but rather seeks to enrich the information about the real world through the use of 3D polygons, text and images, as well as other multimedia elements with a high degree of interactivity (Azuma 1997; Karakus, Ersozlu & Clark 2019; Klimova, Bilyatdinova & Karsakov 2018; Akçayır & Akçayır 2017).

Another growing technology is “Mixed Reality”, which was named by Paul Milgram and Fumio Kishino in 1994 (Milgram & Kishino 1994; Milgram et al. 1994; Reis et al. 2021) and it refers to the combination of the benefits of the AR and the VR (Liu et al. 2021; Tepper et al. 2017). In the MR, real elements and virtual elements interact with each other, all this in a real-time process (Liu et al. 2021).

III. Shortcomings of AR

Although the educational benefits that AR provides in education are undeniable, it is also relevant to establish some concerns that researchers have shown. The content of the application, the accessibility of the didactic method, the prices of the devices (since devices with the optimal features tend to have higher prices), the portability of the digital resources, the experiments in controlled environments and the procedures to develop AR applications (Beck 2019; Akçayır & Akçayır 2017; Solmaz et al. 2021). Many documents also points out the methodological limitations in the studies as well as lack of primary studies about student´s learning achievement (Buchner, Buntins & Kerres 2021), usability issues due the extra cognitive burden for students (Radu 2014; Hincapie et al. 2021) and difficulties in the use of this technology (Lin et al. 2011). These shortcomings can be seen in Table 2.

AR Shortcomings	
- Applications content	- Procedures to develop AR Applications
- Accessibility	- Methodological limitations
- Device´s prices	- Lack of studies about learning achievements
- Portability of the digital resources	- Cognitive burden
- Experiments in controlled environments	- Difficulties in the use of AR technology

Table 2. AR shortcomings

IV. Methodology

With the passage of time, technological advances in computational devices have allowed an increase in the creation and distribution of knowledge. However, this has resulted in a complicated information search, mainly for those who are unfamiliar with the subject. For this reason, in the 1990s the literature review was presented as an alternative for the consolidation and analysis of information (Gough, Oliver & Thomas 2012). The intention of this document is to solve the following research questions (RQ):

- RQ1) What is the research topic of AR documents in Engineering Education present in the downloaded database?
- RQ2) In which countries are these scientific documents being created?
- RQ3) What is the most used software in the downloaded database?
- RQ4) What is the most used hardware by researchers in the downloaded database?

In order to create an appropriate Systematic Literature Review (SLR), the PRISMA standards have been used, which provide guidelines to guarantee the repeatability of the search (Liberati et al. 2009). The identification of the main topic was the first step: Augmented Reality in Engineering Education. It was decided to omit engineering education in Virtual Reality and Mixed Reality in this document, because each one has characteristics that make them unique and therefore have different benefits and weaknesses that deserve their own analysis (as the reader can observe in section IV), like the user´s immersion, which vary in each technology, giving different educational results.

a. Search Strategy

As mentioned before, the first step was the definition of the topic. This led to the election of the Keywords, which were the main elements for the literature search, and those words were "Augmented Reality", "Education", "Training" and "Learning". With the selected terms, the search algorithm was established as: "Augmented Reality" AND ("Education" OR "Training" OR "Learning").

Following this, two specialized databases (DBs) were chosen, ScienceDirect and IEEE. ScienceDirect is a multidisciplinary DB, which has a huge number of documents. Not only that, it is also clear that this DB has high search precision, and it is also recommended to use it when you want to do a thorough review of documents, above abstract and referencing DBs (Tober 2011), and IEEE DB is dedicated to the fields of engineering and computer sciences, making it an excellent option for its relationship with the investigated subject, with also a high number of high-quality documents (Canal et al. 2022).

b. Selection/Exclusion Criteria

When performing the literature search process with the created algorithm, it obtained 415 Documents. To further refine the search, selection and exclusion criteria were established. Initially, 105 duplicate documents were retired. Likewise, the investigations had to be carried out in the last 5 years (2017-2021), which eliminated 63 documents. This period of time was chosen in order to keep up with the most recent trends, such as the proliferation of tools for the development of AR applications (like Apple's ARkit), in addition to the massification of multiple applications, such as Pokémon Go, which trigger the development of this type of applications to this day, and others no less important, such as the creation of the first augmented fair IFEMA LAB 5G, among many others.

Subsequently, 152 documents that did not focus their research on education or engineering were eliminated, and finally, 37 documents that did not focus on engineering education were eliminated. In certain cases, documents focused on STEM education were accepted, because they aim on education in engineering mainly. 4 documents (6.89%) were selected under this rule. The general process resulted in the selection and download of 58 scientific papers. This process and the step by step can be seen in Fig. 1.

c. Data for analysis

The information extracted from each selected document were 1) Title 2) Name of the publishing journal 3) Type of publication 4) Origin of the document (Author´s affiliation) 5) Funding 6) Year 7) Keywords 8) Research area 9) Used software 10) Used hardware & 11) Outcome.

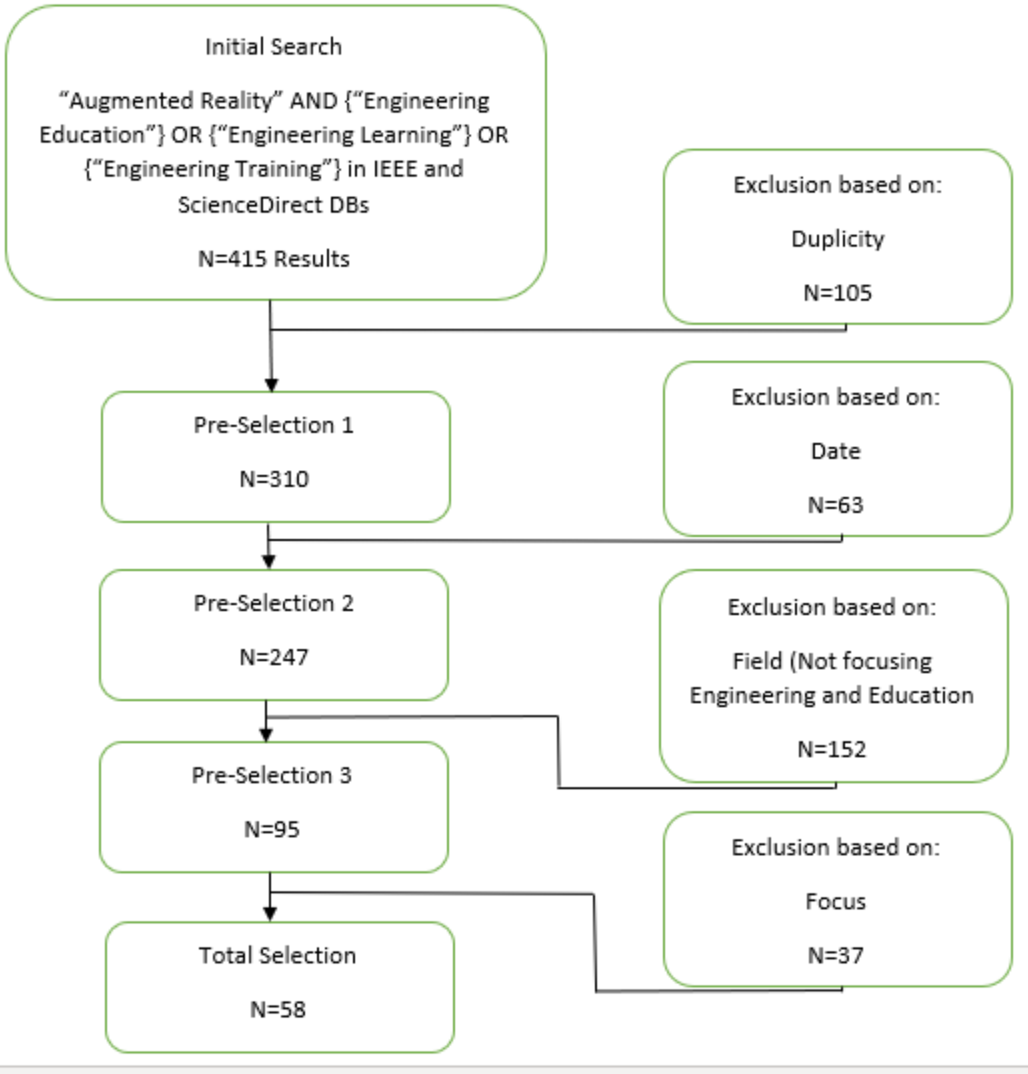

Figure 1. SLR process

V. Results

RQ1) What is the Research Topic of AR documents in Engineering Education present in the downloaded database?

After the analysis of the documentation in the downloaded BD, it was found that the researchers focused their research on 11 topics. Development & Testing was the most researched topic, meaning that 23 papers (39.66%) were focused on developing new AR tools and testing them on engineering students. The next topic was Development, meaning that 15 documents (25.87%) focused on creating an AR tool for engineering students, but it has not been tested or validated. The next most researched topic was Quality of Education, with 8 papers (13.79%. These works were focused on verifying how AR, as a didactic tool, affects the educational process of engineering students. Next, the Analysis of the different AR techniques and tools and its evolution through time was found out with 2 works (3.45%). In fifth place, is Intention of Use, where it studied the willingness of the engineering students to use AR tools in their educational process. All found topics can be seen in Table 3.

Research Topics	Documents	%
Development – Testing	23	39.66 %
Development	15	25.87 %
Quality of Education	8	13.79 %
Analysis	2	3.45 %
Intention of Use	2	3.45 %
Literature Analysis	2	3.45 %
Quality of Education – Testing	2	3.45 %
Analysis – Testing	1	1.72 %
Bibliometric analysis	1	1.72 %
Development - Intention of Use	1	1.72 %
Testing	1	1.72 %

Table 3. Research topics.

RQ2) In which countries are these scientific documents being created?

The 58 documents were written by authors from 27 nations around the world. The most active authors were those from Germany and India, each country credited with the creation of 7 documents (12.07). These countries are followed by China, Mexico, Portugal, Spain and The United States with 4 papers from each country (6.90%). Australia and Colombia are each credited with 3 papers (5.17%) and Ecuador closes the first ten countries, with 2 produced papers (3.45%). The 10 countries that produced the most articles on the subject discussed in this work, can be seen in Table 4.

Countries	Documents	%
Germany	7	12.07 %
India	7	12.07 %
China	4	6.90 %
Mexico	4	6.90 %
Portugal	4	6.90 %
Spain	4	6.90 %
United States	4	6.90 %
Australia	3	5.17 %
Colombia	3	5.17 %
Ecuador	2	3.45 %

Table 4. Countries.

RQ3) What is the most used software in the downloaded database?

Of the total of 58 documents downloaded, 38 (65.51%) reported some type of software development and the use of 58 different computerized programs across these 38 papers. Some researchers used a single program in their development, while others used two or more programs. The most used software to develop AR Applications was Unity – Unity3D, mentioned in 20 of the 38 documents (52.63%). It is important to note that both programs can be used for the development of applications in 2D and 3D, and many authors do not differentiate between the versions used. The main difference is that Unity3D has higher computational requirements for 3D modeling, but both can perform the same development without any inconvenience, therefore it was decided to group the name in Unity - Unity3D. Next is Vuforia, mentioned in 11 documents (28.95%), Blender with 6 mentions (15.49%), Microsoft Visual Studio with 3 mentions (15.79%) and Python, also mentioned on 3 occasions (15.79%). Table 5 presents the 10 most used pieces of software.

Software	Mentions	%	Developer	Type of Software
Unity – Unity 3D	20	52.63 %	Unity Technologies (Unity Technologies, 2021)	Development of 2D/ 3D games and apps
Vuforia	11	28.95 %	PTC Inc. (PTC 2021)	Development of AR apps
Blender	6	15.79 %	Open Source (Blender 2021)	Design/Development of 3D models/ Multimedia elements
Microsoft Visual Studio	3	7.89 %	Microsoft Corp. (Microsoft 2021)	Programming
Python	3	7.89 %	Python Software Foundation (Python	Programming
CalcPlot3D	2	5.26 %	Paul Seeburger (MMA 2021)	Numerical Operations/ Simulations
LabVIEW	2	5.26 %	National Instruments (NI 2021)	Programming/ Simulations
Mathematica	2	5.26 %	Wolfram (Wolfram 2021)	Numerical Operations/ Simulations/Data Sciences
MATLAB	2	5.26 %	MathWorks (MathWorks 2021)	Numerical Operations/ Simulations
OpenGL	2	5.26 %	Silicon Graphics Inc. (Khronos 2021)	Development of 2D/ 3D apps

Table 5. Software.

RQ4) What is the most used hardware by researchers in the downloaded database?

Similar to the use of software, not all the investigations used hardware. In fact, it was found that 35 documents of the 58 chosen (60.34%), registered the use of at least one physical element. Smartphones were the items most used by the authors in their research, being mentioned in 7 of the 35 documents (20%). It was not specified if these devices had Android or IOS operating systems. Next are the tablets (without specifying IOS or Android operating system) with 6 uses (17.14%), Microsoft HoloLens with 5 mentions (14.25%), and Desktop Computers & Unspecified Mobile Devices with 4 mentions of use each (11.43%). Table 6 shows the most used pieces of hardware can be seen.

Hardware	Mentions	%
Smartphone	7	20 %
Tablet	6	17.14 %
Microsoft HoloLens	5	14.28 %
Desktop Computer	4	11.43 %
Unspecified Mobile Device	4	11.43 %
Arduino	3	8.57 %
iPad	3	8.57 %
Laptop Computer	3	8.57 %
Android Smartphone	2	5.71 %
Raspberry Pi	2	5.71 %

Table 6. Hardware (Individual).

Grouping the elements by hardware family, it can be noticed that mobile devices are the ones that receive the focus of the researchers, being used in 24 of the analyzed documents (68.57%). The second most used elements are the AR glasses, with 9 mentions of use (25.71%). Closing the top three are Computers with 7 mentions (20%). All the grouped hardware can be seen in Figure 2.

Hardware Family	Specific Hardware	Mentions of use
Mobile Devices	Smartphones	7
24	Tablets	6
	Unspecified Mobile device	4
	iPad	3
	Android Smartphone	2
	iPhone	1
	Telephone Headset	1
AR Glasses	Microsoft HoloLens	5
9	Epson Moverio BT-300 Eyeglasses	1
	Meta 2 Glasses	1
	Meta Optical See-through AR Glasses	1
	Trimble XR10	1
Computers	Desktop Computer	4
7	Laptop Computer	3
Other Hardware	Arduino	3
2	Raspberry Pi	2
Cameras	Action Camera Glasses	1
6	GoPro Hero 4	1
	Infrared Camera	1
	Optris PiConnect Camera	1
	Unspecified Camera	1
	Webcam	1
VR HMD	HTC VIVE	1
2	Unspecified VR device	1
Printer	Unspecified 3D Printer	1
1		
Projector	Unspecified Projector	1
1		

Figure 2. Hardware (Grouped)

Additionally, target hardware was also established, where it was found out that the efforts of the researchers were oriented to the development of AR applications on mobile platforms. Due to their wide use, mobile devices such as smartphones and tablets are the preferred platforms. Of the documents found, 23 (65.72%) have these devices as target hardware. 9 scientific papers

(25.71%) used AR glasses as their target hardware, followed by 2 documents that used HMDs (5.71%) and 1 investigation that used a projector for AR activities (2.86%).

VI. Results Analysis

Once the analysis of the information extracted from each downloaded document was completed, the research questions posed were solved. In RQ1) What is the research topic of AR documents in Engineering Education present in the downloaded database? It was found that the efforts of a large part of the researchers are concentrated in the development of new applications based on AR and the testing of these, with the intention of creating new educational methods that improve the learning process of engineering students. Answering the RQ2) In which countries are these scientific documents being created? The largest amount of scientific documentation on engineering education comes from two countries: Germany and India. In RQ3) What is the most used software in the downloaded database? It is clear that the most used software is Unity – Unity3D. There are multiple advantages in using Unity to develop applications such as : part of Unity´s source code is available (Mizutani, K. Daros & Kon 2021), offers a relatively simple development system (Liu 2021), it is compatible with a wide variety of platforms of mobile devices and video game consoles (Kim et al. 2014), supports C# and JavaScript (Poyasok et al. 2020), got a wide arrange of effects and physics , present benefits for educators and students (Unity Technologies 2021), a rich toolset, intuitive workspace, ease of testing and editing, smooth communication between the graphical and programming part, wide program compatibility (Kim et al. 2014), robust particle system and great interactivity (Zhang & Hu 2017). However, Unity also presents some technological dependence due characteristics of its engine (Mizutani, K. Daros & Kon 2021), meaning that the software may present performance issues under certain hardware. Lastly, for RQ4) What is the most used hardware by researchers in the downloaded database? The answer is Mobile Devices, especially Smartphones and Tablets. This could be related with the relative low prices of these devices and their high usage between the engineering students.

VII. Researchers' focus: Student Motivation

AR has proved to be a very effective tool, specially in 3 areas: Motivation, Attitude and Learning Achievement (Buchner, Buntins & Kerres 2021; Solmaz et al. 2021). Of these, motivation represents a challenge for educators that is being addressed with AR applications. Previously there were abstract concepts (such as magnetic fields) that were difficult to explain to students (Solmaz et al. 2021; Shiba & Imai 2020; Knierim, Kiss & Schmidt 2018) generating frustration and other negative emotions that affected the knowledge transfer process (Kaur, Mantri & Horan 2020). For this reason, the visualization of 3D elements in AR have been proven to be an excellent form of motivation, which inspires students to carry out their activities (Di Serio, Ibáñez & Kloos 2013; Ibáñez et al. 2020; Liono et al. 2021). There are additional factors that affect motivation as well, such as depression, anxiety, and panic attacks that are also being treated with AR Classrooms (Swaminathan, Rajabooshanam, and Lydia 2020). The importance of student motivation has become so evident that it has been one of the most recurrent themes in investigations about AR in engineering education (Swaminathan, Rajabooshanam, and Lydia 2020; Di Serio, Ibáñez & Kloos 2013; Kaur, Mantri & Horan 2020; Ibáñez et al. 2020; Khan, Johnston & Ophoff 2019).

After reviewing all the downloaded literature, it is indisputable to say that student motivation is one of the main focuses of researchers since it is well known that traditional methods contain many shortcomings. However, In the review carried out, the impact of AR in engineering students in the long term was not studied, nor were comparisons made between devices. It is well known that in developing nations, high-end tablets and smartphones are difficult to acquire for the majority of the population, so many students acquire low-end devices, commonly affecting the performance of computer programs and applications.

It can be noted that some developing countries, like Colombia and Ecuador, are betting on AR in education, so it can also be understood that less-wealthy nations can benefit from the technological massification and the use of free software for AR app development (Unity and Blender for example), creating new educational opportunities. This represents a great motivational advance for students, especially in institutions that, due to lack of resources, cannot have fully equipped laboratories.

There are still many additional questions to be answered and one of them is: What is the proper way to present this technology to engineering students? Although the efficiency of AR educational support been demonstrated (Danaei et al. 2020; Cadavieco, Goulão & Costales 2012; Moro, Smith & Finch 2021), What protocols must be followed in order to obtain an efficient knowledge transfer and keep the interest and motivation of the students? It has already been established in other documents the need to make a correct presentation of AR technology (Chen 2006), but this seems to be an issue not addressed or even fully acknowledged by the investigations consulted for this SLR.

IX. Recommendations for a proper development

The use of AR for educational purposes has shown positive results in the knowledge-transfer process, motivating students and encouraging them (Bourguet et al. 2020; Shiba & Imai 2020; Jacob, Warde & Dumane 2020). Educational AR apps have proven to be effective to motivate female students, so it can be used to stimulate the enrollment of women in STEM majors or subjects. Additionally, the academic accompaniment by a teacher seems to improve the intention of use of AR software by users. (Alvarez-Marin, Velazquez-Iturbide & Castillo-Vergara 2020).

The choice of the target hardware is important. There are dedicated devices, like Microsoft HoloLens, that have benefits, but also drawbacks, such as obstruction of vision, high cost, impossibility of use for people who wear glasses and low resolution of the images. In contrast, cell phones and tablets offer high resolution and affordable prices, but they have AR library problems, which extends the development period (Kim et al. 2014). Also, some cheaper mobile devices may offer a low-quality camera, which can affect the tracking and recognition of QR codes (Babak & Kryukov 2018). Therefore, in some cases, high-capacity smartphones or tablets may be required, which can discourage their use specially to low-income students.

The choice in terms of software is wide, as each developing program has pros and cons that must be analyzed. As mentioned above, Unity offers good simplicity and wide device compatibility (Liu 2021; Kim et al. 2014). Unreal engine is a robust and flexible tool (Chu & Zaman 2021), but it lacks the wide Unity compatibility, for example Unreal is not compatible with Vuforia (Solmaz et al. 2021). Additional software, such as Blender, may be required for the design of 3D models, and AR libraries like ARToolKit, an open-source code with inadequate documentation (Babak & Kryukov 2018), limiting its use to the inexperienced developer.

A good interface design has proven to be a significant aid to students in their educational process (Matoseiro Dinis et al. 2017). The way the information is presented in the application interface can improve the user experience (Al Akil, Ahmed & Saboor 2020). The use of images in AR has proven to be especially effective when handling complex content is required (Liu et al. 2019). It is imperative that all educational content used in the software is reviewed and endorsed by experts on the subject (Akçayır & Akçayır 2017).

Additionally, interactivity can be considered a must, since it increases the user´s motivation (Anastassova et al. 2007; Al Akil, Ahmed & Saboor 2020) and it is important to emphasize the value that students give to computerized programs and apps that are easy to use (Del Bosque, Martinez & Torres 2015). Haptic elements in AR software must be carefully analyzed, since it improves the user´s immersion, but can tax the performance of the device (Zhu, Cao & Cai 2020).

A finding highlights the importance of testing the AR tool in scenarios that are not suitable with the ideal of removing a user from their comfort zone (Scaravetti & Doroszewski 2019). Furthermore, it is important to test the software with a larger group of students, in order to eliminate one of the most common limitations, the low size of the sample (Urbano & Restivo 2018).

Lastly, it is essential to maintain constant communication with the end user to create an adequate experience, in addition to being able to correct weak aspects of the software (Wei, Liu & Wang 2019; Vásquez-Carbonell 2021).

X. Conclusion

It is important to recognize the initiatives of researchers and teachers to create new ways to reach the students' attention and motivate them. Augmented Reality offers a novel way to meet this goal by creating new didactic tools, some of them combining pieces of hardware such as Arduino, Raspberry Pi and a 3D Printer.

In addition to solving the 4 raised questions in this investigation, the importance of AR tools and applications for student motivation was also found. Using this technology, students' understanding of abstract concepts is facilitated. However, there is still work to be done, like finding the proper method to present this technology to a classroom, which is not explained in the vast majority of the analyzed documents, in fact, this topic is only mentioned in one document, and in a superficial way. Not only that, but it has also not been established whether the application of AR in the long term maintains the levels of interest of the students or if it declines, if the novelty disperses from the student´s mind.

Additionally, a section with the recommendations made by consulted researchers was created. This will serve as a guide for those who are interested in developing AR applications in engineering education. This advice guide for a correct development of AR apps was not found in any revised paper, so this section is presented as an extremely useful novelty.

There are still many elements to analyze, but the truth is that AR represents a better future for engineering education not only for its ability to present information in a more dynamic and entertaining way, but also for its ability to motivate students to carry out their academic plan. This article presents relevant information to get the most out of this technology, so it is necessary to disseminate these results to stimulate the use of AR education in engineering.

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