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# Virtual Technologies Trends in Education

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## ABSTRACT

Virtual reality captures people's attention. This technology has been applied in many sectors such as medicine, industry, education, video games, or tourism. Perhaps its biggest area of interest has been leisure and entertainment. Regardless the sector, the introduction of virtual or augmented reality had several constraints: it was expensive, it had poor ergonomics, or implied too much work to create contents. Recent technological innovations, including the rapid adoption of smartphones by society, have facilitated the access to virtual reality and augmented reality of anyone. In addition, several large companies like Apple, Facebook, Samsung, and Magic Leap, among others, have increased their investment to make these technologies to improve their accessibility within the next few years. Educational institutions will benefit from better accessibility to virtual technologies; this will make it possible to teach in virtual environments that are impossible to visualize in physical classrooms, like accessing into virtual laboratories, visualizing machines, industrial plants, or even medical scenarios. The huge possibilities of accessible virtual technologies will make it possible to break the boundaries of formal education.

**Keywords:** Virtual reality, Augmented reality, Virtual Learning Environment, Educational Technology

## INTRODUCTION

Year 2016 has been presented in the media as the year which virtual reality can reach households through consumers' electronic devices like smartphones (Cellan-Jones, 2016; Sag, 2016). This will involve the arrival of these technologies in educational environments by supporting different learning styles, and easing teaching and learning processes.

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**State of the literature**

- The potential benefits of Virtual Reality and Augmented Reality to conduct educational activities has been investigated during last decade.
- The investment to facilitate the access to massive scale virtual contents in Q1 2016 was $1.2 billion, and it is expected to obtain $120 billion profits in 2020. The investment is mainly focused to create virtual contents and to manufacture headsets to visualize these contents.
- Educational sector will be one of the most benefited from improving the accessibility and affordability of virtual technologies as a result of the potential of these technologies as a teaching tool.

**Contribution of this paper to the literature**

- This paper provides a comprehensive understanding of Virtual and Augmented Reality technologies and discusses the possibilities of using technologies in education.
- The authors present a brief description of how recent virtual technologies can be integrated into newer educational scenarios and teaching practice.
- It stresses what are the advantages and limitations of using virtual technologies in educational environments.

Virtual Reality (VR) industry market is expected to grow $15.9 billion by 2019 (Fildes, 2015), and according to analyst Kota Ezawa from Citi Research, 2016 is the year that virtual reality takes off in earnest (Ezawa, 2016). Digi-Capital's Virtual/Augmented Reality (VR/AR) Report 2016, and VR/AR deals database totalize $686 millions of investments in Augmented and Virtual Reality during 2015, and $1.2 billion just in the first quarter of 2016; this investment in Q1 2016 represents roughly 25 times VR/AR investment in Q2 2014 (Digi-Capital, 2016). According to Digi-Capital´s report this year could be the tipping point for VR/AR investment, and it looks like it could drive growth to $120 billion by 2020.

The same report (Digi-Capital, 2016) reveals that nearly 50% of $1.2 billion invested during Q1 2016 has been dedicated to the development of Head Mounted Displays (HMD, Fig. 2), and around $800 millions of the total investment during Q1 2016 has gone into Magic Leap, one of the four giants in the VR/AR industry (Magic Leap, Oculus, Blippar, and Mindmaze). These four giants sum a business volume rounding $9 trillion: Magic Leap ($4.5 billion), Oculus ($2 billion), Blippar ($1.5 billion) and Mindmaze ($1 billion). The expectations of Magic Leap (https://www.magicleap.com) are impressive regardless the investment: in opposition to companies like Facebook, Oculus or Microsoft, which include a layer of digital images on top of the real world through special eyeglasses, Magic Leap pretends to project digital light fields into the user's eyes for greater realism (Tilley, 2016). Even without Magic Leap's, the remaining Q1 2016 in-vestment was 45% higher than the previous quarter (Fig. 1). The leading VR/AR investment sec-tors in the last year were VR/AR hardware, video, solutions/services, games, advertising/marketing, consumer apps, distribution, tech and peripherals.

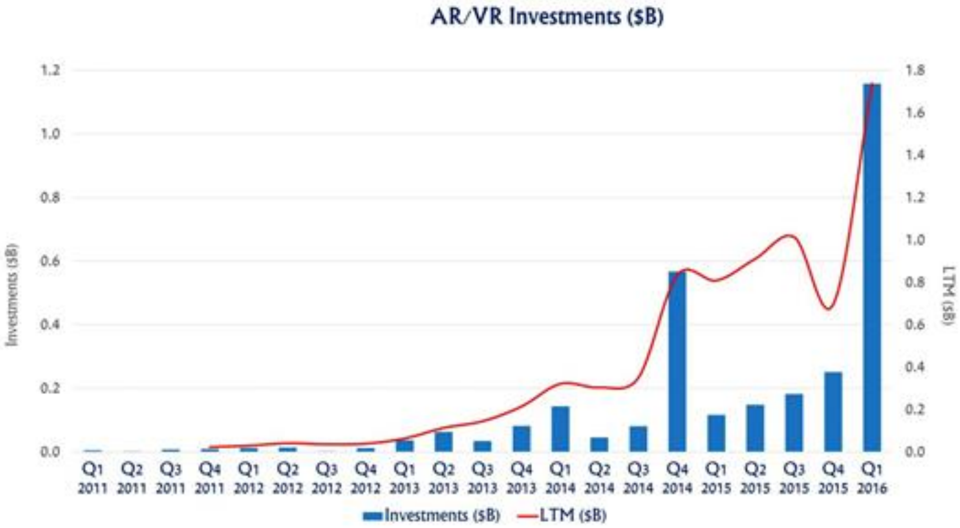

**Figure 1.** VR/AR Investments (2011-2016). Image reproduced with permission of Digi-Capital.

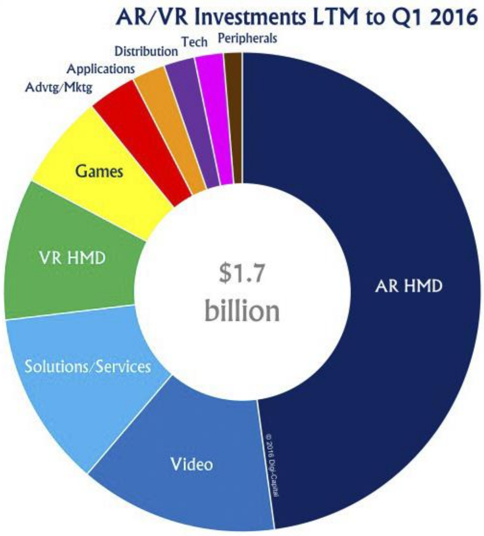

**Figure 2.** VR/AR investments in Q1 2016. Image reproduced with permission of Digi-Capital.

Research and development in Virtual Reality technology is not just focused on mobile devices, but on a whole ecosystem that is being built around smartphones, including applications for training and education, sales, engineering, etc. This symbiosis between VR/AR and mobile phones is possible thanks to the development of compatible glasses with affordable prices.

However, to VR/AR become popular contents are required. These contents may offer the possibility of having virtual experiences in many sectors such as education, logistics or medicine. This is because newer applications are able to transform Virtual and Augmented

Reality into some-thing useful, like simulators to conduct training in professions that require precision like surgery, or maintenance in high risk facilities like nuclear power plants. But creating VR/AR contents by consumers is also being possible; being videos one of users' most interesting multimedia contents in social networks, 360º videos will cause a greater feeling of immersion when using social net-works. Newer smartphones are integrating cameras allowing to shoot 360º videos and images, so that the possibility of users creating virtual reality contents is real. One initiative to share users' VR generated contents is Facebook's plans to integrate meeting virtual spaces, among other actions.

It is true that most consumers may not be yet convinced of what VR/AR offers. There are still many challenges, since VR/AR companies have focused their efforts on video-games users, but other consumers do not have to know necessarily what VR/AR is, or what devices are required, like special glasses, HMDs, or cameras. Even so, all VR/AR companies want to win the race for this business, which is a sector that, according to experts on this field, will be converted in the next few years in a global business (Digi-Capital, 2016). China is one of the most important places where consumer electronics are made, and this country introduces into the European and American markets most of the glasses and mobile devices required to consume VR/AR contents. According to the expectations, sales of virtual reality helmets will soar during 2016 (Fig. 2); it is estimated that more than a million units could be sold. Numbers may be even higher after the emergence of Microsoft's Hololens, their new virtual reality glasses (Ezawa, 2016).

Many VR/AR manufacturers have announced their products during the first half of 2016. In this context, HTC Vive promised a 360º immersive experience by using a laser tracking system so that the user can walk anywhere and make any movements. The new coming generation of Samsung's smartphones in 2016-2017 will include apps to share and view virtual contents with their HMD viewfinder Gear VR. Samsung aims to make the creation of 360º videos simple to encourage the purchase of HMDs. Besides, LG has engineered a device able of taking 360º pictures and 360º videos with 2K resolution, and a light virtual reality viewer including two mini HD screens connected to the smartphone.

The feeling of being anywhere makes precisely contents more attractive, friendly, and interesting, but it is the easing of creating contents by end-users what increases the potential of VR/AR in the field of education. This paper deepens precisely in this aspect, and shows how virtual technologies can be used, and how students can interact in an immersive virtual experience with other students and teachers. In addition, this paper shows trends and future learning scenarios using these technologies, and describes what are benefits and limitations of VR/AR in educational environments

## DESCRIPTION OF VIRTUAL TECHNOLOGIES

### Definition of VR and AR

The concept of Virtual Reality (VR) refers to a whole simulated reality, which is built with computer systems by using digital formats. Building and visualizing this alternative reality requires hardware and software powerful enough to create a realistic immersive experience (e.g. VR helmets or dedicated glasses and 3D software). Augmented Reality (AR) superposes synthetic elements like 3D objects, multimedia contents or text information onto real-world images (Hsieh & Lin, 2011), increasing its possibilities of interaction with the user. Both Virtual Technologies (VT) are a current topic in the Internet Technologies (ITs) industry, but VT are not restricted to specialized areas anymore (e.g. aerospace industry); at present, these technologies are used in many disciplines, including education, medicine, geography, advertising, etc.

Rosenblum & Cross (1997) indicate three key aspects linked to any VR system: Immersion, Interaction and Visual Realism. Immersion is created by surrounding the user with virtual technologies and devices (Wu, Lui, Wang & Zhao, 2015), e.g. virtual glasses, gloves with movement sensors, HMDs, surround sound, and any other element creating sensorial stimuli, or sensors per-mitting the user to interact with a virtual environment as in a real environment. In this way, VR simulates the physical presence of the user in a virtual environment, which is categorized as sensory-motoric, cognitive, and emotional (Björk & Holopainen, 2004), but VR also creates an immersive 3D spatial experience when the user perceives that belongs to a virtual world (e.g. a play-er in a videogame), that is affected by his or her perceived feeling of artificiality and transportation (Benford, Greenhalgh, Reynard, Brown & Koleva, 1998). To be credible, this perception requires real-time interaction (Riva, 2006), so that the user requires instant feedback of his or her movements, position, and sensations. This feedback permits the user reacting and sending commands to a computer by using trackers, gloves, keyboards, or any other input device simulating real-world user's reactions. Output devices (visual, aural, or haptic) should create a realistic illusion, so that hardware and software should be able to render detailed and realistic virtual scenarios, and have to handle geometry, texture, and physical models to be credible.

By contrast, Augmented Reality (AR) does not necessarily requires creating a realistic illusion, and can be considered as an extension of VR, which mixes a vision from real world with virtual elements to create a real-time mixed reality. However, there is not a sharp line delineating a frontier between AR and VR; in this regard, the concept of reality virtuality continuum (Milgram & Kishino, 1994) stablishes a continuous scale between a totally real environment and a totally virtual environment (Fig. 3); Benford, Greenhalgh, Reynard, Brown & Koleva (1998) propose a classification linked to the artificiality and transportation perceived by the user (Fig. 4). In fact, AR is not just real-time computer imagery overlaying onto physical objects in precise positions (Zhou, Duh & Billinghurst, 2008), but virtual and physical objects can interact (Höllerer & Feiner, 2004) by creating new ways of human-computer interaction (Ludwig & Reimann, 2005)

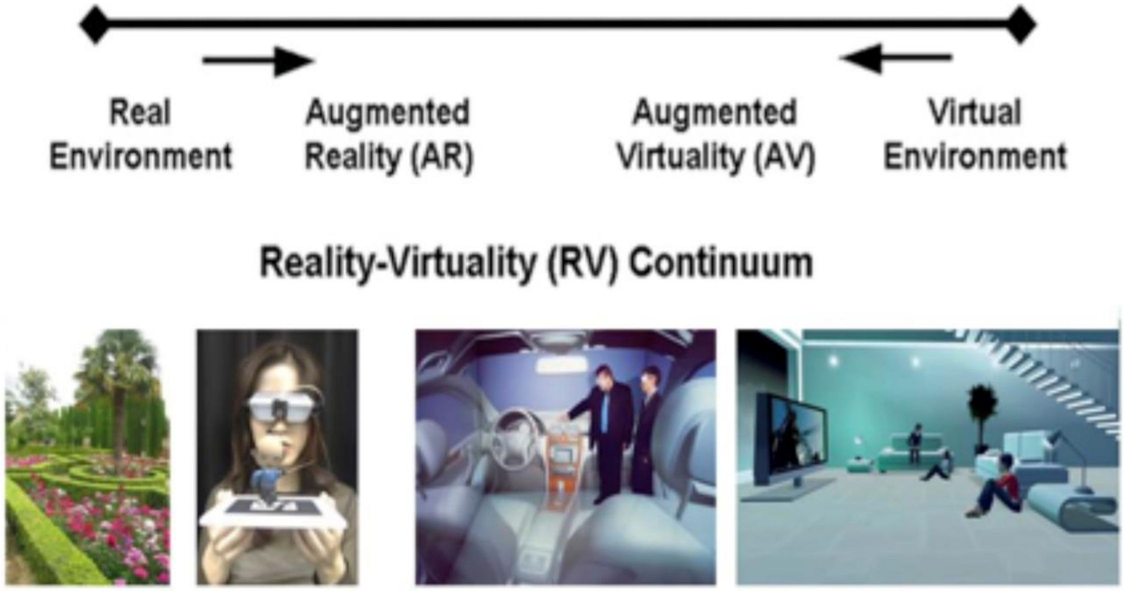

**Figure 3.** Milgram´s reality-virtuality continuum (Milgram & Kishino, 1994).

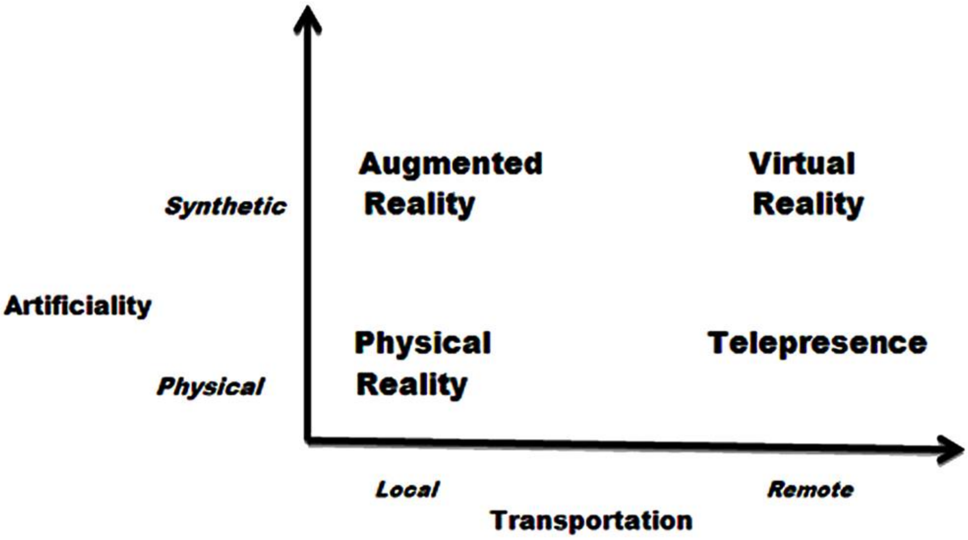

**Figure 4.** Classification of shared spaces according to transportation and artificiality (Benford, Greenhalgh, Reyn-ard, Brown, & Koleva, 1998).

## Types of VR and AR

As seen, virtual technology systems may have several ways to enhance interaction and immersion. Basically, any VR/AR system can be classified as immersive, semi-immersive, and non-immersive (Bamodu & Ye, 2013) (Fig. 5). If an immersive system creates the feeling of being exploring a whole virtual world, a semi-immersive (e.g. by using several projection screens instead of glasses) or a non-immersive system (e.g. computer displays) create some degree of realism, but without a so enhanced feeling of "being there". However, different implementations may have different degrees of immersion; the following represents a non-comprehensive list of virtual technology categories that produce different immersive perceptions (Riva, 2006):

- *Cabin simulators*, used mainly to recreate and simulate a real cabin, like a cockpit, a car, or a vessels' bridge. Cabin's windows are replaced by high-resolution computer displays, and it may be equipped with surround sound. Furthermore, it is possible to add move-ment for increased realism, as a response action to user's controls.
- *Projected reality*, that consists of a real-time user's moving avatar, which is visualized on a wide screen.
- *Augmented Reality*, that requires dedicated immersive glasses or a mobile device to visualize augmented objects overlapping the surrounding real environment.
- *Telepresence,* that can be used to influence and operate something that is real, but in a different location, like a laboratory, a nuclear power plant, etc.
- *Desktop virtual reality*, which just requires a regular computer display. Interaction with the virtual world is limited to the possibilities of a desktop computer mouse or a joystick, but it does not require any expensive hardware or software, so it is relatively easy to de-velop.
- *Visually coupled systems,* which are mostly associated to military aviation. The system places the screens at user's eyes level, and connects user's head movement with the displayed image. The system includes sensors to track user's eyes movement, and it is able to determine what is he or she looking at.

**Figure 5.** Classification virtual reality by its immersive degree.

## Virtual technologies to visualize and create VR/AR contents

One of the challenges faced by VR/AR companies recently was creating less complex and more affordable hardware, which is a key factor to popularize virtual technologies. Latest hardware developed by these companies is classified into three categories:

1. Smartphones mounted on headsets (**Fig. 6**a, b).
2. Dedicated Head Mounted Displays (HMDs) (**Fig. 6**c, e, f).
3. Augmented Reality glasses (**Fig. 6**g, h, k).

Mobile devices like smartphones have actually processors powerful enough, among other characteristics, to make them suitable for VR/AR visualizing. Cheap headset boxes to insert users' smartphones (e.g. Google Cardboard**, Fig. 6**b) is all additional hardware required to have an affordable immersive experience. If a more immersive experience is required, dedicated HMDs (e.g. Oculus Rift, Samsung Gear, Cark Zeiss VR One, or HTC Vive) add more realism at the expense of using an external computer to process more realistic synthetic objects. However, low cost headsets are becoming interesting technological gadgets to a market that has been expanding 30%-50% annually, and it is expected a price drop and improved performance during next five years (Ezawa, 2016). This will be a key factor to the expansion of virtual technologies in the short term.

Regarding Augmented Reality glasses, these are not designed to isolate its user from the surrounding reality, but to superpose synthetic information on a transparent glass. Some of these glasses require an external pad consisting in an Android device used to execute and to control its AR apps (e.g. Epson Moverio); others do not need an external device (e.g Microsoft Hololens), or are more advanced and are equipped with sensors that permit users to interact with virtual objects naturally (e.g. META).

Samsung Gear(a) Cardboard (b) Oculus(c)

HTC Vive (d) LG (e) Playstation VR (PSVR) (f)

Hololens (g) Meta (h) Moverio BT200 (k)

**Figure 6.** Popular models of Head Mounted Displays for VR and AR in 2016.

To create a deeper immersive feeling, external sensors have the potential of capturing gestures and user's position. Examples to this are Leap Motion, Microsoft Kinect, and MYO (**Fig. 7**); Leap Motion and Microsoft Kinect are able to capture user's movements, but MYO goes one step further by capturing hand's movement precisely, which is useful to virtually control robots or machines. Other devices (Omni, Fig. 8a) are integrating the concept of free movement in the virtual environment, or even are designed to create 3D virtual objects like painting on the air (Tilt Brush, **Fig 8**b)

**Figure 7.** Sensors to interact with virtual objects and information

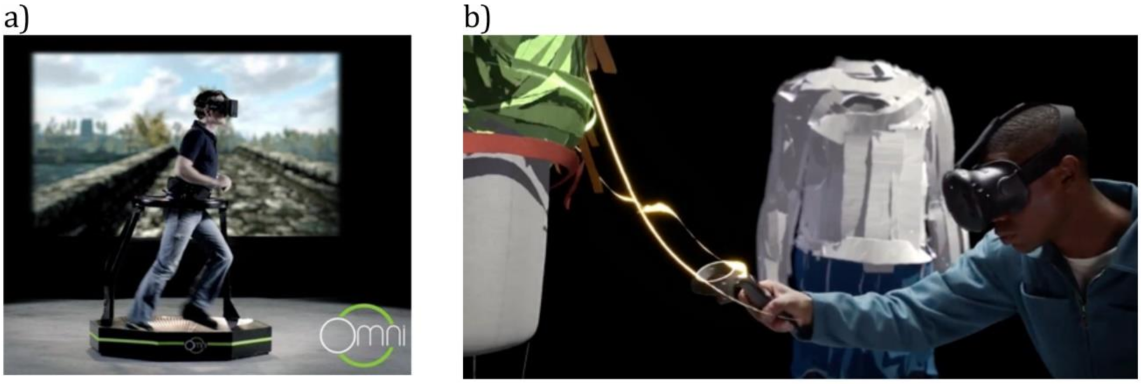

**Figure 8.** a) Virtuix Omni device, http://www.virtuix.com/. b) Drawing with Tilt Brush, http://www.tiltbrush.com.

However, contents are needed to make VR/AR more attractive. This is why companies have embarked in finding ways to ease sharing and creating VR/AR contents. The following are just some examples to illustrate this tendency: Facebook360 is a Facebook community aimed to show others how to create immersive and interactive 3D videos (https://facebook360.fb.com); Google is preparing the launch of their platform DayDream VR in 2016 (https://vr.google.com/daydream/), which is aimed to share high quality VR contents; Jump (https://vr.google.com/jump/) is another Google's initiative consisting in a multi-camera circular support and software to create high resolution 3D videos; Faceshift (http://www.faceshift.com) is a marker-less face motion capture software, producing realistic face expressions in virtual characters animations.

## VIRTUAL TECHNOLOGIES IN EDUCATION

Virtual technologies have the potential of making students feeling more committed and motivated (Kerawalla, Luckin, Seljeflot, & Woolard, 2006); research on these technologies opens new paths for teaching and learning (Chen & Tsai, 2012). There are numerous case studies that investigate this area when using virtual technologies in educational environments (Harris & Reid, 2005; Martin-Gutierrez, Saorin, Contero, Alcaniz, Perez-Lopez, & Ortega, 2010; Di Serio, Ibañez & Kloos, 2013), but these studies tend to be focused on specific experiences and topics. Thus, it is important to understand effective instructional designs for a better integration of VR/AR (Dun-leavy, Dede, & Mitchell, 2009), because there is still not a clear vision of how to integrate these technologies in a stable way into an educational process. In this regard, there are difficulties like the resistance of traditional learning environments to integrate educational innovations, the opposition of teachers to adopt new technologies out of their comfort zone, and the costs involved to implement and maintain these technologies. However, taking into consideration the quick evolution of mobile technologies like smartphones and tablets, the use of VR/AR is more feasible and affordable for educational institutions and students than ever before, so it is relevant to understand what are the plusses and minuses of using these technologies in educational environments.

### Advantages of using virtual technologies in education

There are studies in the scientific literature linking virtual technologies with improvements in students' academic performance and motivation (Harris & Reid, 2005; Sotiriou & Bogner, 2008; Di Serio, Ibáñez, & Kloos, 2013; Martín-Gutiérrez & Meneses, 2014; Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014; Holley, Hobbs, & Menown, 2016), students' social and collaborative skills (Kaufmann, Steinbugl, Dünser, & Gluck, 2005; Martin-Gutiérrez, Saorín, Contero, Alcaniz, Perez-Lopez, & Ortega, 2010), and students' psychomotor and cognitive skills (Feng, Duh, & Billinghurst, 2008). These advantages of using VR/AR technologies are similar to those ones obtained when using Computer Assisted Instruction (CAI), like computer-based simulations. The success of using CAI is based in students' empowerment effect, instructional capabilities of the system, using of newer instructional approaches, and the development of cognitive skills and positive attitudes (Chou, 1998, as cited in Zacharia, 2003). Even if simulations just represent real-life, there are features enhancing a real-life experience (Ferry et al., 2004), and these simulations make possible students to explore new domains, make predictions, design experiments, and interpret results (Steinberg, 2000).

In the same way, Virtual Reality is motivating, and students have also a positive attitude towards using VR in their learning process (Mikropoulos, Chalkidis, Katsikis, & Emvalotis, 1998). Furthermore, VR grabs and holds students' engagement, probably because it is exciting and challenging to interact, create, and manipulate objects in a virtual environment, but also because VR adds precision, and permits visualizing objects and processes otherwise impossible to show in a real environment. What is more, virtual technologies make it possible to be exposed to abstract ideas by using models that can be interacted, so it also eases exposing students to knowledge by following a constructivist approach (Winn, 1993). Precisely, this constructivist approach is able to promote a full student-centred learning experience, given that students are main performers when experimenting and practicing with virtual objects (Winn, 2002).

Therefore, virtual technologies encourage students to be active learners, because VR/AR promote decision-taking when interacting with virtual environments, permitting autonomous exploration, understanding complex concepts, creating new experiences, and learning by doing. In addition, real-time interaction permits visualizing results instantly, so students are able to take decisions based on these results to reach their learning goals, increasing their learning performance and cognitive skills (Kotranza, Lind, Pugh, & Lok, 2009). But it is also possible to interact collaboratively, so virtual environments also boost interaction and collaboration among students. These advantages promote better students' engagement by using immersive experiences, reducing distractions, and creating positive attitudes when students have better feedback to reach their learning goals easily. Immersion is precisely one of the best advantages of using VR/AR, because it provides a first person experience. This idea is aligned with Dales' learning cone (Dale, 1969), given that a well-designed virtual experience is closer to a direct purposeful experience than just educational television or exhibits.

Moreover, Virtual Technologies are at the forefront of technological development. Recent advances make these technologies more accessible, and now disabled students have the opportunity of participating in virtual experiences (Lange, et al., 2010), albeit these advances also benefit regular students by creating more accessible experiences (e.g. by using their mobile devices, or by accessing to virtual spaces when enrolled in distance-taught courses).

To sum up, there are four main aspects regarding the advantages of using virtual technologies:

- Virtual technologies increase students' motivation and engagement. Students have an immersive experience and feel as protagonists, while studying 3D models that enhance their learning experience.
- Virtual technologies allow a constructivist approach of learning. Students are free to interact with virtual objects and other students. As a result, students can investigate, experiment, and obtain feedback, resulting in an experience that improves their learning.
- Virtual technologies are now affordable and accessible. Recent technological advances ease access to VR/AR with smartphones, tablets, and videogame devices. Complex devices are not a requirement anymore, and students can access to shared VR contents through common online platforms such as YouTube. In addition, disabled students have easier access to virtual environments and are able to interact with virtual objects and other students.

- Virtual technologies allow more interaction than conventional learning materials. By using VR/AR, students feel immersed while interacting with concepts, objects and processes by using headsets, tactile gloves, and motion sensors. This immersion permits to experiment environments with realistic objects that could not be accessible otherwise.

## Virtual learning scenarios

Today, it is not just about using virtual technologies in classroom, but technological improvements allow various alternatives with different levels of interaction and immersion. One of these possibilities are Virtual Worlds (VWs) like Second Life (http://secondlife.com), which may be used or adapted to train students in any specific discipline, such as construction safety (Le, Pedro, & Park, 2014), or medicine and health education (Boulos, Hetherington, & Wheeler, 2007). VWs are user-shapeable to create a flexible virtual learning environment, and it is possible to use services like sharing any user's computer desktop, showing presentations, attending videoconferences, drawing on whiteboards, sharing files, etc. (Fig. 9). These VWs facilities are accessible through computer desktop VR, but the increasing affordability of HMDs will allow a more immersive learning experience. This will make it possible to incorporate 3D VR into virtual learning environments, like it is being used in VR cinema (Fig. 10). However, a higher degree of immersion and interactivity is desirable, and it will be possible when students can move freely and interact with virtual elements like in a real world, by means of easy-to-use and affordable body-motion sensors. Looking ahead, ideally students could interact with virtual objects without requiring any device, like with Magic Leap's proposal.

**Figure 9.** Virtual World webconference

**Figure 10.** Interactive Virtual Reality cinema room (https://thevrcinema.com/)

## VR/AR examples in education

Research literature shows numerous implementations of VR/AR in educational environments, from virtual teaching by using 3D Virtual Worlds (3DVW) (Jarmon, Traphagan, Mayrath, & Trivedi, 2009; McKerlich, Riis, Anderson, & Eastman, 2011), to other more specific experiences like a VR vehicle driving simulation (Kuei-Shu, Jinn-Feng, Hung-Yuan, & Tsung-Han, 2016), or using virtual technologies to train spatial skills (Gutiérrez, Domínguez, & González, 2015). The following are just other representative projects, experiences, and software developments linked to educational environments:

- The *Aumentaty* project, developed by the *Labhuman* laboratory (http://www.labhuman.com) at the Polytechnic University of Valencia in Spain, and the *BuildAR* project, developed by the *HITLabNZ* laboratory (http://www.hitlabnz.org) at the University of Canterbury in New Zeeland. Both projects aim to integrate AR in the class-rooms by providing tools to create educational AR apps.
- Research projects funded by the European Union like CONNECT (2005-2007), CREATE (2004), and *ARiSE* (2006-2008) are aimed to integrate informal learning in a learning environment.
- Researchers have used *Aurasma* (http://www.aurasma.com) extensively used as a tool in different learning strategies (Parton & Hancock, 2012; Connolly & Hoskins, 2014).
- *Science Center to Go* project (http://www.sctg.eu) is another example of using AR to improve scientific education by manipulating and experimenting with virtual objects.
- *Magicbook* (Billinghurst, Kato, & Poupyrev, 2001) is one of the first implementations of AR by using textbooks. This type of books can be used as regular textbooks, but visualizing virtual contents like 3D objects, animations or videos is possible by using a computer webcam or a mobile device.

## Limitations of using virtual technologies in education

The rise of technologies able to exchange massive amounts of digital information (e.g. social networks and mobile devices) have created a new communicative scenario (Buckingham & Rodriguez, 2013) based on interaction. Younger students have always lived surrounded with these technologies and are digital natives (Prensky, 2001), but this does not mean students are competent using technologies in an educational environment (Margaryan, Littlejohn, & Vojt, 2011); virtual technologies are not an exception to this. The use of newer innovative technologies does not involve necessarily pedagogical innovations; it is required to design Virtual Learning Environments (VLEs) beginning with pedagogical affordances to maximize learning outcomes (Fowler, 2015). This pedagogical scaffolding of VLEs requires academic staff to be involved actively when designing virtual learning scenarios to obtain maximum learning benefits.

## CONCLUSION

By following Ezawa's conclusions (Ezawa, 2016), VR/AR will steadily evolve during next 10 years, becoming a popular everyday technology among population, including educational environments.

In the past, these experiences were costly and limited to specific sectors like aerospace industry or nuclear power, but there are three factors contributing to the democratization of VR/AR: power and capabilities of newer mobile devices, increased investment to the development of virtual technologies, and access to user-generated virtual contents through social networks. This democratization will increase accessibility and affordability of VR/AR, and these technologies will be something as usual as mobile technologies within next few years, making it easier to integrate VR/AR. During next decade, virtual technologies will revolutionize the way people interact in a similar way Internet and smartphones did. Low cost headsets will be an additional, accessible, powerful, and affordable complement to mobile devices. As a consequence, it will be possible to conduct immersive experiences by interacting with objects, concepts, or processes, as a regular learning workflow in any educational level, from primary school to higher education.

Thus, it makes sense to take advantage of these technologies to facilitate learning, but the way virtual technologies are used will impact learning outcomes. It is possible to use VR/AR to access knowledge as being a passive viewer, or just as following a list of instructions as in a traditional lab practice, but the cornerstone of virtual technologies is immersion and interactivity, by means of cheaper HDMs and moving sensors. This means that students will have first-person experiences, and will take decisions and interact after obtaining feedback, so that learning will be possible after a process of analysis and reflection. What is more, students will have the possibility of creating and sharing knowledge by creating and sharing virtual objects and experiences. Therefore, the limits of using VR/AR in an educational environment is not in technology itself, but in how this technology is used and how students learn. Virtual learning experiences should not be just aimed to gain knowledge, so it is required to design these learning environments from a constructivist approach to obtain full learning benefits.

## REFERENCES

ARiSE Project (2006-2008). Retrieved June 24, 2016 from http://www.arise-project.org/

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Journal of Educational Technology & Society, 17*(4), 133–149.

Bamodu, O., & Ye, X. M. (2013). Virtual Reality and Virtual Reality System Components. In *Advanced Materials Research* 765, 1169-1172.

Benford, S., Greenhalgh, C., Reynard, G., Brown, C., & Koleva, B. (1998). Understanding and constructing shared spaces with mixed-reality boundaries. *ACM Transactions on Computer-Human Interaction, 5*(3), 185–223. doi: 10.1145/292834.292836.

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The MagicBook: a transitional AR inteface. *Computers & Graphics*, *25*(5), 745-753.

Björk, S., Holopainen, J. (2004). *Patterns in Game Design.* Charles River Media, Boston, MA.

Boulos, M. N. K., Hetherington, L., & Wheeler, S. (2007). Second life: An overview of the potential of 3-D virtual worlds in medical and health education. *Health Information & Libraries Journal*, *24*(4), 233-245. doi:10.1111/j.1471-1842.2007.00733.x

Buckingham, D., & Rodríguez, C. (2013). Learning about Power and Citizenship in an Online Virtual World. *Comunicar*, *20*(40), 49-58. doi:10.3916/C40-2013-02-05.

Cellan-Jones, R. (2016). *2016: the year when VR goes from virutal to reality*. Retrieved July 5, 2016 from http://www.bbc.com/news/technology-35205783.

Chen, C. M., & Tsai Y. N. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education, 59*(2), 638–652. doi: 10.1016/j.compedu.2012.03.001.

Chou, C. (1998). *The effectiveness of using multimedia computer simulations coupled with social constructivist pedagogy in a college introductory physics classroom*. Unpublished doctoral dissertation, Teachers College-Columbia University, New York.

CONNECT Project (2005-2007). Retrieved June 18, 2016 from http://www.ea.gr/ep/connect/.

Connolly, E., & Hoskins, J. (2014). Using iPads to Teach Year 7 Induction with Aurasma. *The School Librarian*, *62*(1), 6.

CREATE project (2004). Retrieved June 18, 2016 from http://www.cs.ucl.ac.uk/research/vr/Projects/Create/

Dale, E. (1969). *Audio-visual methods in teaching.* New York: Dryden.

Digi-Capital (2016). *VR/AR investment in 2015 breaks out near $700 million.* Available on: http://www.digi-capital.com/ (http://goo.gl/aD5pib).

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education*, *68*, 586-596.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7–22. doi: 10.1007/s10956-008-9119-1.

Ezawa, K. (January 2016). Virtual & Augmented Reality. In Investment Themes in 2016. In: Citi Global Perspectives & Solution. Citigroup Inc. Retrieved June 15, 2016 m from https://www.citivelocity.com/citigps/ReportSeries.action?recordId=45

Feng, Z., Duh, H. B.L., & Billinghurst, M. (2008*)*. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. *Paper presented at the7th IEEE/ACM international* *symposium on mixed and augmented reality (ISMAR)*, Cambridge, UK. doi: 10.1109/ISMAR.2008.4637362.

Ferry, B., Kervin, L., Turbill, J., Cambourne, B., Hedberg, J., Jonassen, D., & Puglisi, S. (2004). The design of an online classroom simulation to enhance the decision making skills of beginning teachers. *Australian Association for Research in Education.* Retrieved June 16, 2016, from http://goo.gl/tGszqD

Fildes, N. (2015). *2016 is the year that VR will take off.* . Retrieved June 18, 2016 from http://raconteur.net/technology/2016-set-to-be-year-virtual-reality-takes-off.

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British Journal of Educational Technology*, *46*(2), 412-422. doi:10.1111/bjet.12135.

Gutiérrez, J. M., Domínguez, M. G., & González, C. R. (2015). Using 3D Virtual Technologies to Train Spatial Skills in Engineering. *International Journal of Engineering Education 31*(1), 323-334.

Harris, K., & Reid, D. (2005). The influence of virtual reality play on children's motivation. *Canadian Journal of Occupational Therapy*, *72*(1), 21-29.

Höllerer, T., & Feiner, S. (2004). *Mobile augmented reality. Telegeoinformatics: Location-Based Computing and Services.* Taylor and Francis Books Ltd., London, UK, 21.

Holley, D., Hobbs, M., & Menown, C. (2016). The Augmented Library: Motivating STEM Students. *Networks*, *19*, 77-84.

Hsieh, M. C., & Lin, H. C. K. (2011). A Conceptual Study for Augmented Reality E-learning System Based on Usability Evaluation. *CISME, 1*(8), 5–7. doi:10.5963/CISME0108002.

Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education*, *53*(1), 169-182.

Kaufmann, H., Steinbugl, K., Dunser, A. & Gluck J. (2005). General training of spatial abilities by geometry education in augmented reality. *Cyberpsychology & Behavior, 8*(4), 330.

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). Making it real: Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality (Waltham Cross), 10*(3-4), 163–174. doi:10.1007/s10055-006-0036-4.

Kotranza, A., Lind, D. S., Pugh, C. M., & Lok, B. (2009, October). Real-time in-situ visual feedback of task performance in mixed environments for learning joint psycho-motor-cognitive tasks. *Paper presented at the 8th IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, Orlando, FL.

Kuei-Shu, H., Jinn-Feng, J., Hung-Yuan, W., & Tsung-Han, L. (2016) Application of the Environmental Sensation Learning Vehicle Simulation Platform in Virtual Reality. *Eurasia Journal of Mathematics Science and Technology Education 12*(5), 1477-1485. doi:10.12973/eurasia.2016.1525a.

Lange, B. S., Requejo, P., Flynn, S. M., Rizzo, A. A., Valero-Cuevas, F. J., Baker, L., & Winstein, C. (2010). The potential of virtual reality and gaming to assist successful aging with disability. *Physical medicine and rehabilitation clinics of North America, 21*(2), 339-356

Le, Q. T., Pedro, A., & Park, C. S. (2014). A social virtual reality based construction safety education system for experiential learning. *Journal of Intelligent & Robotic Systems*, *79*(3-4), 487-506. doi:10.1007/s10846-014-0112-z.

Ludwig, C., & Reimann, C. (2005). Augmented reality: Information at focus. *Cooperative Computing & Communication Laboratory, 4*(1). Universitat Paderborn.

Margaryan, A., Littlejohn, A., & Vojt, G. (2011). Are digital natives a myth or reality? University students' use of digital technologies. Computers & Education, 56, 429-440. doi:10.1016/j.compedu.2010.09.004.

Martín-Gutiérrez, J., Saorín, J. L., Contero, M., Alcaniz, M., Pérez-López, D. C., & Ortega, M. (2010). Design and validation of an augmented book for spatial abilities development in engineering students. *Computers & Graphics, 34*(1), 77–91. doi:10.1016/j.cag.2009.11.003.

Martín Gutiérrez, J., & Meneses Fernández, M. D. (2014). Applying Augmented Reality in Engineering Education to Improve Academic Performance & Student Motivation. *International Journal of Engineering Education*, *30*(3), 625-635.

McKerlich, R., Riis, M., Anderson, T., & Eastman, B. (2011). Student perceptions of teaching presence, social presence and cognitive presence in a virtual world. *Journal of Online Learning and Teaching*, *7*(3), 324.

Meta. "Meet Meta", metavision.com. [Online]. Retrieved June 8, 2016 from http://www.metavision.com.

Mikropoulos, T., Chalkidis, A., Katskikis, A., & Emvalotis, A. (1998). Students' attitudes towards educational virtual environments. *Education and Information Technologies, 3*(2), 137-148.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12), 1321-1329.

Parton, B. S., & Hancock, R. (2012). Animating the Inanimate using Aurasma: Applications for Deaf students. In *Society for Information Technology & Teacher Education International Conference*, 1, 3743-3745.

Prensky, M. (2001). Digital Natives, Digital Immigrants. *On the Horizon, 9*(5), 1–6. doi:10.1108/10748120110424816.

Riva, G. (2006). Virtual reality. *Encyclopaedia of Biomedical Engineering*. London: John Wiley & Sons.

Rosemblum L. J. Cross R. A. (1997). The challenge of virtual reality. In W. R. Earnshaw, J. Vince, H. Jones (Eds.), *Visualization & Modeling* (pp. 325–399). San Diego, CA: Academic Press.

Sag, A. (2016). *2016 Could be Nvidia´s "Virtual Reality Year"*. Retrieved July 5, 2016 from http://www.forbes.com/sites/moorinsights/2016/04/26/2016-could-be-nvidias-virtual-reality-year/#5561accde1bd

Sotiriou, S. & Bogner, F. X. (2008). Visualizing the invisible: Augmented reality as an innovative science education scheme. *Advanced Science Letters, 1*(1), 114–122. doi:10.1166/asl.2008.012.

Steinberg, R. N. (2000). Computers in teaching science: To simulate or not to simulate? Physics Education Research, *American Journal of Physics Supplement 68*(7), and S37-S41.

Tilley, A. (February 2016). Augmented Reality Startup Magic Leap Closes $794 Million Investment As It Enters Pilot Production Phase. Retrieved June 18, 2016 from http://goo.gl/hRdTXq.

Winn, W. (1993). *A conceptual basis for educational applications of virtual reality* (Technical Report TR-93-9). Seattle, Washington: Human Interface Technology Laboratory, University of Washington. Retrieved from http://www.hitl.washington.edu/publications/r-93-9/.

Winn, W. (2002). Research into practice: Current trends in educational technology research: The study of learning environments. *Educational Psychology Review*, *14*(3), 331-351.

Wu, F., Liu, Z., Wang, J., & Zhao, Y. (2015, March). Establishment virtual maintenance environment based on VIRTOOLS to effectively enhance the sense of immersion of teaching equipment. In *Proceedings of the 2015 International Conference on Education Technology, Management and Humanities Science (ETMHS 2015)*. Atlantis Press. doi:10.2991/etmhs-15.2015.93.

Zacharia, Z. (2003). Using interactive simulations to enhance students' explanations regarding physical phenomena. *Computer based learning.3* (B), 472–476.

Zhou, F., Duh, H. L., & Billinghurst, M. (2008). Trends in augmented reality traching, iteraction nd display: A review of ten years in ISMAR. *Proceedings of the Mixed and Augmented Reality, ISMAR 7th IEE/ACM International Symposium* (pp. 193-202). Cambridge: IEEE.

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