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New Challenge in Education: Enhancing Student's Knowledge through Augmented Reality

Abstract: The evolution of Augmented Reality has been fast and global, and as it could not be otherwise, its potential in education has begun to be explored. Indeed, we truly believe this technology could be especially valuable in the classroom. First of all, it allows teachers to show virtual objects in the real-world environment which otherwise would be impossible to show. On the other hand, it can also be used to enhance collaborative tasks, as well as encourage socializing and inclusive activities for people with special needs. This chapter gives a brief overview of how the implementation of Augmented Reality can be improved in the school environment not only by showing its versatility and possibilities, but also by describing a number of proposals for applications in different educational levels.

Keywords: Augmented Reality, Mobile Augmented Reality, Educational Technology, Pedagogy, Learning, Didactical Methodologies.

1. Introduction

The 2005 Horizon Report (Johnson et al. 2005), which foresaw the technologies expected to have a major impact on educational context in the next five years, spoke about Augmented Reality for the first time as an instrument capable of offering additional information to individuals about their physical environment and providing enriching learning experiences; moreover, this report predicted the implementation of this emerging technology in the educational context around the years 2009 – 2010. Though the 2006 Horizon Report repeated that the widespread implementation of Augmented Reality technology in the educational system should take place within four or five years (Johnson et al. 2006), while the Horizon Reports 2010 and 2011 (Johnson et al. 2010, 2011) delayed later the generalized implementation of Augmented Reality in the educational field until 2012 – 2014, the fact is that the forecast remains unfulfilled. In this chapter we aim to show that the use of Augmented Reality technology in schools should be encouraged, as it improves the teaching-learning process and, by extension, students' acquisition of knowledge. Thus, we will begin by explaining

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why this technology is still not a mainstream technology in education. Subsequently, we will present a series of resources which allow that even the layman can create Augmented Reality applications. Lastly, we will describe many uses made of Augmented Reality technology in different educational stages and curriculum areas.

2. Definition of Augmented Reality

According to Lee (2012), the term 'Augmented Reality' was coined in the 1990's by Tom Caudell. To date, Augmented Reality technology has been used in many fields, such as medicine (Kilgus et al. 2015), architecture, clinical psychology (Chicchi et al. 2015), and education, among others. As previously stated, in this chapter we will draw attention to the possibilities that Augmented Reality opens up in the process of learning, for they have already been highly appreciated by educational experts and researchers (Bower et al. 2014, Lee 2012, Nincarean et al. 2013, Wu et al. 2013).

However, although studies on Augmented Reality have intensified during the last few years, the term 'Augmented Reality' has been defined in different ways. Thus, we will begin by clarifying this concept. We will not focus on the technology needed for using Augmented Reality, but on its characteristics and possibilities. It can therefore be stated that, even though Augmented Reality is based on the technology that makes it possible, its conceptualization cannot be restricted to such technology. From this point of view, Augmented Reality could be regarded in a wider context as any technology capable of combining real and virtual information in a meaningful way (Klopfer/Sheldon 2010). To shed light on this point, Milgram et al. (1994) referred to a Reality-Virtuality Continuum that ranges from the purely real context to a purely virtual one. If we move away from the poles of this continuum, we can find mixed reality, which is defined as the joint presentation of objects of the real world and objects of the virtual one. Mixed reality is thus composed of Augmented Reality and augmented virtuality (AV). Specifically, Augmented Reality results from combining the virtual world with the real one, with the particularity that the latter is presented to a larger extent that the former. By contrast, AV consists in adding real world objects to a virtual context, but the information provided to the user is mostly virtual.

> Within this framework it is straightforward to define a generic Mixed Reality (MR) environment as one in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the RV continuum. (Milgram et al. 1994, 283)

This concept of mixed reality is illustrated by a simplified representation of the Reality-Virtuality Continuum in Figure 1:

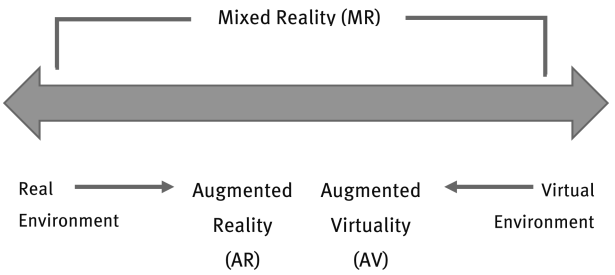

Fig. 1: Reality-Virtuality (RV) Continuum. Milgram et al. (1994, 283).

3. Augmented Reality Technologies: From QR codes to immersive virtual reality

We apply the term 'Augmented Reality' to all those technologies that make possible to superimpose in real time virtual images, markers or information upon real-world scenes (cf. De Pedro/Martínez 2012, Durlach/Mavor 1995, Fombona et al. 2012, Fundación Telefónica 2011). The result is an enriched or Augmented Reality which is obtained by overlaying digital information onto the physical reality perceived through our five senses: in other words, it is a new lens through which we can see a more complete picture of the world (Fundación Telefónica 2011).

Computers with Internet connection have allowed us to live in an interconnected world, but the fact that connectivity has been extended to other devices such as smartphones, tablets, watches and even eyeglasses, makes it possible to receive the information we need in a very natural, easy and fast way. Indeed, we no longer need to wait for the moment when we can isolate ourselves by sitting down in front of a computer. Just as the human being got a broader view of the world when standing upright than when walking stooped, we also have a broader view of reality by using computers. Thanks to devices like smartphones, Augmented Reality is being increasedly used (Fundación Telefónica 2011), for its scope has been extended to include entertainment, marketing, tourism, education and health.

The term 'Augmented Reality' is also applied to a set of technologies more sophisticated than those mentioned above, as they enable us to reproduce

three-dimensional images, recreate virtual worlds, and manipulate virtual objects: this is what is known as immersive virtual reality (Fundación Telefónica 2011). Keeping in mind the increasing complexity of the technology used in Augmented Reality, authors distinguish a series of levels (Prendes 2015):

Level 0. Physical World Hyper Linking. In this level, codes – of bars or two-dimensional ones like the QR codes – are activated and connected to associated contents such as hyperlinks and simple images, texts, audios or videos (see figure 2).

Fig. 2: QR Code. Wikimedia (https://commons.wikimedia.org/wiki/File:Codigo_QR.svg)

There exist different resources that make possible the personalized creation of this type of codes which is currently used in the educational and other fields. Here are some examples: Kaywa (http://qrcode.kaywa.com/), Visualead (http://www.visualead.com/), QR Stuff (http://www.qrstuff.com/) o GOQR.me (http://goqr.me/).

Level 1. Marker Based AR. Markers are black and white geometrical shapes – usually squares – which contain simple and asymmetrical designs that allow three-dimensional objects superposition and recognition (see figure 3).

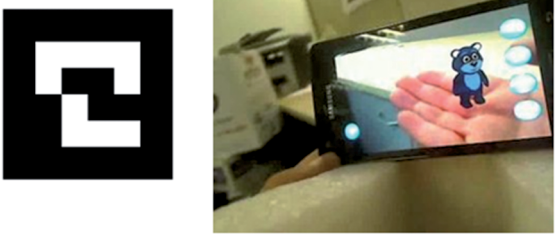

Fig. 3: Marker. Wikimedia (https://en.wikipedia.org/wiki/Augmented_reality)

Level 2. Markerless Augmented Reality. This technology makes possible the superposition of information on a physical world scene by using either images as activators, or objects and persons that activate virtual information even through the use of GPS technology without the need for markers (see figure 4).

Fig. 4: Markerless AR. Wikimedia (https://commons.wikimedia.org/wiki/File:MediatedReality_on_iPhone2009_07_13_21_33_39.jpg)

Level 3. Immersive Virtual Reality or Augmented Vision. In comparison with other levels, this is a disruptive technology inasmuch as computer and mobile device screens are replaced by eyeglasses, lenses or special sensors that immerse us in three-dimensional worlds (see figure 5)

While technology involved in Augmented Reality systems is becoming more complex, their use is also increasingly expanding. According to a recent report (see Research and Markets 2015), the installed base of actively used mobile Augmented Reality apps will increase from 135 million in 2014 to 2.2 billion by 2019;

Fig. 5: Augmented vision. Wikimedia (https://en.wikipedia.org/wiki/Google_Glass)

moreover, this growth might create a market of $1.6 billion for mobile Augmented Reality apps in 2019.

4. Augmented Reality in the educational environment

Although the use of Augmented Reality involves increasingly sophisticated devices and tools, the question we are particularly interested in analyzing is how this technology makes learning more meaningful or, in short, improves the learning process. As Bower et al. (2014) pointed out, the superposition of diverse multimedia items to physical world scenes makes Augmented Reality a cognitive support in understanding and performing complex tasks. In this sense, Wu et al. (2013) list a series of contributions of Augmented Reality to the educational field:

A. Projection of specific concepts in three dimensions, which will no doubt facilitate students a better understanding of such concepts.
B. An ubiquitous and collaborative learning through mobile devices and geo-location systems that enable users to be wireless connected at any time and place.
C. The student's feeling of presence, immediacy and immersion in virtual environments, which ends up generating virtual learning communities.
D. Visualization of the invisible, for example, by making it possible to represent concepts like magnetic fields or air currents.

E. Connection between formal and informal learning, as Augmented Reality awakes students' interest in the learning process.

Augmented Reality technologies generate experiences that stay in students' memory longer than if teachers use other resources like traditional or even digital books, slide presentations or video views (García 2014, Jabr 2014, Sommerauer/Müller 2014, Zhang et al. 2014). Furthermore, when digital information in two or three dimensions is added to the pictures of world scenes provided by a Smartphone or a tablet, attention is often automatically drawn to the screen (García 2014), which should be kept in mind when designing didactic resources. After all, it has also been proved that Augmented Reality helps increase students' motivation and improves their academic results (Wei et al. 2015, Bower et al. 2014, Di Serio et al. 2013, Chen/Tsai 2012).

A further advantage of Augmented Reality has to do with the fact that the more senses are involved in a given experience, the better it is retained (García 2014). To this should be added that Augmented Reality makes it possible to manipulate information as if it were an object in space, which increases our knowledge of specific issues. Thus, Augmented Reality can be of great help for the brain when organizing quickly scattered information (Fundación Telefónica 2011). Indeed, when we overlay supplementary items onto physical world scenes, we are already giving meaning to disjointed information by relating it to our prior knowledge. Related to this, Augmented Reality enables students to modify the scale in which virtual objects are shown, so that they can manipulate them in order to better understand characteristics and relationship of objects that are too small – for example, molecules – or too big – for instance, heavenly bodies (Johnson et al. 2010). Sheehy et al. (2014) called this way of learning 'Augmented Learning' to highlight the process in which the real or physical world joins the virtual one through diverse technological devices that enrich our knowledge with new data and experiences.

Like other emerging technologies, Augmented Reality can constitute a strong partner in inclusive education. Indeed, Augmented Reality has already proven to be effective in treating people with autism spectrum disorder. Specifically, Augmented Reality has been useful in capturing their attention and helping them understand non-verbal clues, which created problems in interpreting emotions and facial expressions (Chen et al. 2015, 2016). Augmented Reality has also been used with students with physical disabilities. By way of example, software Scratch 2.0 designed by the Media Laboratory at MIT (http://scratch.mit.edu) was used together with a webcam to catch movements. Participants could watch the computer screen in front of them, while two speakers were put on

the floor. Thus, when participants did the correct foot lifting, they received dynamic pictures and sounds as feedback (Lin/Chang 2015).

It can be stated that Augmented Reality technology fits perfectly with those emerging pedagogies that are intended to overcome traditional pedagogy (Muñoz 2014). Traditional schools are characterized by rigid and overloaded curricula as well as the classic figure of the teacher as the unique holder of knowledge which is taught through oral presentations to passive pupils who must learn by heart in a classroom too distant from daily life. Innovative teachers who are aware of this bad practice stand by the principles of the Escuela Nueva (New School) and implement a teaching-learning process through which students learn by doing, as they must construct autonomously their own learning while the teacher orientates and motivates them. That is why we teachers and educational researchers currently talk so much about problem- and project-based learning, multiple intelligences, competences, experiential education, gamification, flipped and flexible learning, among others (Adell/Castañeda 2012). In the last years, terms like 'learning by doing', 'action learning' or 'experience learning' are often used: although they are not synonymous, for each one presents different nuances, they all emphasize the importance of experience, contact with the surrounding reality, and practical applications, so that they can be framed within what has generally been called 'active learning'. This educational trend can be traced back to the figure of John Dewey (1938), who stressed the relevance of experience in formal learning as well as the necessity of relating teaching-learning processes to daily life. Other eminent specialists like Piaget, Bloom, Freire, Gardner or Lewin have also highlighted the importance of experience for achieving learning goals. Nowadays almost nobody casts doubt on the students' need of experimenting and learning to do. We are increasingly aware of the necessity of connecting contents and activities, theory and practice, processes and results, without falling in the sterile activism.

A common feature of all of these pedagogical models is that the student plays an active role, to the extent that he becomes the protagonist of his own learning. By the way, this student's central role is also characteristic of Augmented Reality applications in the educational field (Muñoz 2014). As stated above, Augmented Reality facilitates ubiquitous learning by helping the student learn at any time and place. Thus, Augmented Reality fits with these active pedagogies inasmuch as it makes possible that students from all educational levels and in all subject areas learn comprehensively by doing, investigating, and developing their creativity. In fact, Kesim and Ozarslan (2012) remarked that Augmented Reality combines aspects of the ubiquitous (present anywhere all the time), tangible (clearly perceptible) and social (as it promotes collaboration) technology. In

a nutshell, Augmented Reality is fully compatible with a number of pedagogical approaches like the following ones (Bower et al. 2014):

- Constructivist learning. Augmented Reality facilitates that students immerse themselves in their tasks and make more profound and lasting connections in their knowledge framework by using diverse kinds of information.
- Situated learning. Augmented Reality places the student in an actual learning context by incorporating daily life into the classroom.
- Game-based learning. These Augmented Reality games submerge the student in a virtual narrative in which he must play a given role that prepares him to deal with daily life.
- Enquiry-based learning. Augmented Reality makes it possible to experiment with virtual models that are immersed in real world scenes.

5. Reluctances to the application of Augmented Reality in the educational field

As we have seen, the benefits of applying Augmented Reality to the educational field are obvious; however, Augmented Reality is still far from being a mainstream technology in education. To shed light on this issue, we turn now to expose some reasons.

To begin with, innovations that turn out to be rather disruptive – and which thus require changes in very consolidated habits – are much more difficult to accept than those which simply involve a mere quantitative change in what we already know (Moore 2015). Such is the case of Augmented Reality – and also of the Internet as well as of personal computers when they were first introduced – as it entails a new way of contemplating the world, accessing information, interacting with other people, and, by extension, of learning and knowing. Hence, teachers need time to adapt to this technology and to be able to value its potential advantages. The same could be said about parents, for research has proven that many parents are still reluctant to accept Augmented Reality technology as a vehicle for their children's learning (Cheng/Tsai 2016).

Besides problems resulting from the lack of technical knowledge required to elaborate Augmented Reality applications (Kerawalla et al. 2006), there is a shortage of tools specifically designed for the educational field (Martin et al. 2011), which has hampered the successful and generalized use of Augmented Reality in the educational environment. These technical constraints are actually being overcome thanks to the use of some specific applications and others which, as we will see next, allow teachers and students to create Augmented Reality contents even without displaying a high level of technical knowledge. How-

ever, teachers are often inadequately prepared to deal with technical problems that may arise at any moment. Of course, such technical training would be necessary in order to avoid that the design of Augmented Reality applications always lies in the hands of computer scientists and technicians who lack pedagogical knowledge or, in other words, are not acquainted with didactic aspects that should be considered when elaborating Augmented Reality educational contents (Billinghurst/Duenser 2012).

Lastly, students who use Augmented Reality applications frequently may become cognitively overburdened due to the vast amount of information they find, the multiple technological devices they must use, and the complex tasks they have to perform (Wu et al. 2013).

6. Uses of Augmented Reality in the educational field

Regarding uses of Augmented Reality in the educational environment, there are some fields and resources worthy of attention (Fundación Telefónica 2011):

- Books: There are currently books with codes, such as the QR, which make it possible to visualize three-dimensional objects and watch videos with the help of an application installed in a technological device.
- Games: Some games show three-dimensional scenarios that can be watched through any mobile device, while others allow players to create virtual objects or people.
- Object modeling: This technology empowers users, amongst other things, to create virtual objects in order to manipulate them, detect anomalies, explore their properties, and interact with other objects.
- Use of standard applications for teaching purposes: A clear example of this is Google Skymap, an open source application that not only allows to see the stars by focusing the camera of a mobile device on them, but also overlays relevant digital information onto their physical image.

New Augmented Reality applications with teaching purposes increasingly emerge throughout the world. Here are some examples:

- Word Lens (http://questvisual.com) serves to translate in other languages words that are focused on by a smartphone camera. Hence, this could be a supporting resource for teaching languages.

- Zooburst (http://zooburst.com) makes it possible for students to create their own digital stories in three dimensions by combining images, texts and audios.
- LearnAR (http://learnar.org) provides a package of ten applications to acquire knowledge about biology, physics, mathematics and diverse languages.

3DU is an Augmented Reality technology that allows users to interact and learn in a virtual university (Estopace 2015).

Particularly noteworthy are those systems like AURASMA (http://aurasma.com), Junaio (http://junaio.com), Layar (http://layar.com) or BuildAR (http://buildar.com) that allow teachers and students to create their own Augmented Reality scenes with images, videos and three-dimensional objects. These systems present very intuitive and simple drag-and-drop interfaces for non-programmers, which greatly simplifies the process of creating Augmented Reality scenes: thus, it is not necessary to be a computer programmer or expert in order to make designs with Augmented Reality. However Cubillo et al. (2015) have developed an easy-to-use application for teachers called UNED ARLE (National University for Distance Education – Augmented Reality Learning Environment), aiming to overcome some constraints that are often encountered when using the abovementioned applications. As they put it:

> It is not usual that they support interaction or more complex behaviors such as modification of the displayed content, evaluation of content, contextualization of contents. To achieve that, some level of programming is necessary, for example, in Layar, where videos, images, and multimedia content can be inserted; however, to add new 3D objects requires some knowledge of programming languages. There are tools like Aurasma, Augment, Zooburst where interaction is easy and intuitive but limited. Aurasma, the positioning and scaling of objects cannot be modified in real time, while in the case of Augment, which allows real-time interaction, it has limited the number of models in its free version to 2, regarding to Metaio, after purchasing the Metaio Creator application, teachers can connect 3D content, videos, audio, and web pages to any form of printed medium. After careful consideration of the features of the most important tools for developing applications or experiences of AR, the decision was made to develop an authoring tool with the power of tools for programmers, which is as easy to use as tools for non-programmers. A specialized tool for learning would be included, allowing representation of virtual content and interaction with it. The evaluation of acquired contents would be made available through "augmented" questions (MCQs), they enable to increase the interest of students in what they are observing, and all of them are characteristics taken into account in the development of UNED ARLE. (Cubillo *et al.* 2015, 780)

After having made reference to these resources and applications, we would like now to describe a series of current uses of Augmented Reality applications in dif-

ferent curriculum areas and educational stages, which could inspire readers with this new way of educating.

6.1 Early childhood education (3 – 6 years old)

The use of Augmented Reality in early childhood education is increasingly widespread, so that we can find many examples at international level that illustrate the extent to which teachers are trying to implement this technology in the students' learning process. Augmented Reality has been applied very creatively in this educational stage to reinforce playful learning. Let us see three brief examples of this. Firstly, Yilmaz (2016) combined the use of Augmented Reality technology and toys to create an application that empowered teachers to overlay cartoons, three-dimensional objects and flash animations onto toys in order to teach concepts related to animals, fruits, vegetables, vehicles, objects, professions, colours, numbers and forms. Secondly, Tomi and Rambli (2013) explained how storybooks aided by Augmented Reality technology improved the process of learning to read in Malaysia (Tomi/Rambli 2013). Thirdly, Huang et al. (2015) have recently used in Hong Kong kindergarten applications like coIAR for early art education, and informed that the assessments of pupils, teachers as relatives were very positive.

Once said this, we will now expose some activities carried out through Augmented Reality technology in early childhood education:

- Become acquainted with the life and work of historical figures through QR codes. On the occasion of International Day of Peace, students in kindergarten had an initial approach to Nelson Mandela's life through videos and images activated by codes. Children had already received a very special postal card containing different QR codes that could be transformed through the application AURASMA into information about a given figure: for instance, where she was born, or which important things she did (see http://lospequesdemicole.blogspot.com.es/2016/01/mensajero-de-paz-nelson-mandela.html).
- Create interactive city maps. The Project Around the world with Willy Fog was intended for 3 years-old students to discover different countries and cultures. To this end, they could use QR codes to activate videos created by them (see http://lospequesdemicole.blogspot.com.es/2014/07/earthquest-la-vuelta-al-mundo-de-willy.html).
- Design and learn geometrical forms. A robot called Bee Bot is programmed to capture QR codes that are transformed into geometrical forms. In this way, children learn basic mathematics and computer skills (see http://lospe

quesdemicole.blogspot.com.es/2015/12/cuerpos-geometricos-robotica-y-realidad.html).

- Convert objects and pictures into Augmented Reality markers by adding virtual layers of videos that were also created by children themselves. Students made a scale model of the human eye with papier-mâché, recorded videos explaining what they had learned, and linked them to their model of the eye through the application Thinglink (see http://lospequesdemicole.blogspot.com.es/2015/06/maqueta-3d-del-ojo.html).
- Recognize and analyze three-dimensional teaching contents. To become acquainted with the human circulatory system, students used a marker that activates the heart, the veins and arteries as three-dimensional objects in order to manipulate and analyze them (see http://lospequesdemicole.blogspot.com.es/2015/04/el-corazon-las-venas-y-arterias-con-ra.html).
- Stimulate and enrich interactive activities like Webquest and Earthquest. A growing number of teachers are designing this kind of activities based on constructive learning. Students usually enjoy when they must discover the solution of diverse problems by using Internet, but they take an even greater interest in these activities if they are combined with the use of Augmented Reality (see http://lospequesdemicole.blogspot.com.es/2015/03/iniciamos-webquest-del-universo.html).
- Reach other students and classrooms. New technologies are becoming widely used to twin classrooms and schools within a single country or even from different continents. In this sense, Augmented Reality may be of great help when working together on joint projects, as it facilitates that students share videos and images (see http://lospequesdemicole.blogspot.com.es/2015/01/queremos-conocer-un-aula-hospitalaria.html).
- Develop reading and writing skills in a creative way. By way of example, the written form of letters can be converted in markers in order to associate them with the spelling and gesture that each student will have previously recorded (see http://lospequesdemicole.blogspot.com.es/2013/11/nos-iniciamos-en-la-lectoescritura.html).
- Create audiovisual contents to provide information on specific objects, or to send greeting cards which include videos recorded by the students themselves (see http://infantic-tac.blogspot.com.es/2013/12/navidades-digitales.html).
- Turn diverse school areas into interactive learning spaces. When a specific issue is tackled at school, QR codes with digital content elaborated by the students may be placed on walls and doors.

- Bring students' pictures to life. There are applications like Quiver (see http://quivervision.com/) which make it possible to colour drawings that are then transformed into three-dimensional objects.
- Acquire basic concepts such as volume. Thanks to applications like Chromville, students can play in virtual three-dimensional worlds (see https://chromville.com/).
- Know the surrounding environment. Students may go out on the street with their teachers to discover the environment by gathering information from QR codes through devices like Smartphones or tablets (see http://enmiaula deinfantil.blogspot.com.es/2016/01/nuevo-proyecto-y-que-hacemos.html).

6.2 Primary education (6 – 12 years old)

As could be expected, Augmented Reality technology has also been used in primary education. Here are some examples:

- First approach to basic musical principles. There are applications like AR learning that allow students to visualize musical instruments in three dimensions, listen their characteristic sound, write notes on a staff, and become acquainted with sound qualities such as pitch, intensity and tone (see http://www.slideshare.net/citecmat/aumentame-edu-2015?ref=http://www.aumenta.me/node?page=5).
- The Aurasma software (https://www.aurasma.com/) empowers teachers and students to project videos where musicians play those very instruments that students are beginning to use. In this way, students have a model to follow while their motivation increases (Roscorla 2013).
- Modern dance practice through programs like Just Dance, thanks to which students can develop their corporal expression following models projected with Augmented Reality technology (see http://www.slideshare.net/citecmat/aumentame-edu-2015?ref=http://www.aumenta.me/node?page=5).
- Library 2.0. It consists in placing QR codes on library and classroom books to enrich them with videos, podcasts or three-dimensional objects (see http://infantic-tac.blogspot.com.es/2013/08/receta-2o-biblioteca-digital-libros-con.html).
- Treasure hunting. This type of playful activity becomes even more interesting for students when they can use QR codes as clues to find the treasure in an amusing yet instructive way (see http://infantic-tac.blogspot.com.es/2013/10/feliz-halloween_24.html).
- Learn linguistic structures through tales. Students can improve their written expression by creating stories which may also be illustrated with pictures

that can be transformed into three-dimensional designs thanks to applcations like ChromVille (see https://docs.google.com/presentation/d/1ihhPQqXDk8joYS8jd8fIWJ3gxCYaVlyu-4n1jnak3eA/edit?pref=2&pli=1#slide=id.g9af23b72d_0_0).
- Get a more realistic view of natural phenomena. With the help of programs like K-Solar System, students can contemplate a three-dimensional reproduction of the solar system as well as analyze the interactions among its elements (see https://docs.google.com/presentation/d/1ihhPQqXDk8joYS8jd8fIWJ3gxCYaVlyu-4n1jnak3eA/edit?pref=2&pli=1#slide=id.g9c3b410b2_0_57).
- Elaborate tourist guides. After taking photographs and recording videos to make presentations of emblematic places, students can create QR codes in order to geolocate all those materials on a map (see http://enmiaula deinfantil.blogspot.com.es/2015/07/proyecto-de-centro-con-codigos-qr.html).
- Children with autism can learn to recognize parts of their body through applications like Pictogram Room (see http://www.pictogramas.org/proom/init.do?method=gameTab).
- Learn history with geolocalized information related to legends and historical ruins, among other things (see https://prezi.com/nnz_gh-w6r4b/aumentame-2014-granada-17-de-mayo).
- Encourage healthy eating habits. Students can learn through QR codes about the fruits and vegetables that they find in the market (see https://www.youtube.com/watch?time_continue=41&v=sdRksbuVvtg).

6.3 High school and professional development (12 – 18 years old)

We can also find examples of learning activities based on Augmented Reality in high school and professional development:
- Guided tours to museums. Visits to museums are part of annual schools programs and are usually arranged by teachers with the aim of students taking full advantage of the visit. Bearing this in mind, students can use Augmented Reality technology not only to gather information on what they will see, but also to read QR codes which are already available in many museums and galleries (see http://www.aumenta.me/node/255).
- Virtual museums in three dimensions. After presenting in three dimensions objects exposed in different museums, students can analyze them in detail

and interact with them (see https://www.youtube.com/watch?time_continue=154&v=Gbb9DR8bRN8).
- Geolocated routes. Students can take advantage of applications like Layar to create their own routes through Augmented Reality in order to know the architectural styles of a city, fauna and flora of a region, and works of a particular artist (see http://www.aumenta.me/node/259).
- Create a laboratory at school or at home. Augmented Reality helps students develop scientific skills, as they may test hypotheses and perform calculations (see https://docs.google.com/presentation/d/1ihhPQqXDk8joYS8jd8fIWJ3gxCYaVlyu-4n1jnak3eA/edit?pref=2&pli=1#slide=id.g9c3b410b2_0_12).
- Process simulation. Students can enhance knowledge on electronics by designing electronic schemes and simulating their functioning (see http://www.slideshare.net/bernatllopis/ponencia-ardutronica-aumentame-2014?ref=http://www.aumenta.me/node?page=13).
- Study on an experimental basis subjects such as chemistry (see https://www.youtube.com/watch?v=2kpFr0XFgFA).
- Study of geometry. Students develop their mathematical competence by interacting with three-dimensional figures created by themselves (see http://www.slideshare.net/citecmat/presentacion-ar-mat-35051813?ref=http://www.aumenta.me/node?page=13).
- Augmented reading workshop. Books read in this workshop may contain codes like QR to visualize three-dimensional objects, watch videos or listen podcasts elaborated either by the students themselves or by publishers (see https://www.youtube.com/watch?v=EzHld8vRRAo).
- Make augmented books. By way of example, students can make a book that shows front, lateral and top view of geometric figures in three dimensions (see http://victormorenocaceres.wix.com/axonometriaenra).
- Construction of three-dimensional prototypes. Students may design models of dwellings adapted for handicapped people thanks to the application Sketchup (see http://www.aumenta.me/node/252).
- Create scenarios to submerge into them through Augmented Reality glasses like the Cardboard visor. In this way, students can implement current teaching principles, e. g. learning by doing (see https://www.youtube.com/watch?time_continue=5&v=5I5JqbfQpsY).
- Improve oral fluency in different languages. Since Augmented Reality can be used to choose an image as marker and associate it with a video, students can talk in different languages about a number of topics or objects in a motivating and funny way overcoming their initial embarrassment (see https://docs.google.com/presentation/d/1ihhPQqXDk8joYS8jd8fIWJ3gxCYaVlyu-4n1jnak3eA/edit?pref=2&pli=1#slide=id.g9c3b410b2_0_57).

- Enrich and support students' presentations. Students should learn to use Augmented Reality as an innovative and useful tool when explaining issues and facilitating that other people understand one's own argument (see http://labtic.org/emigrandoentremares/).
- Recreations. Students can recreate the classical world by using videos recorded by themselves (see http://illargonauta.blogspot.com.es/).
- Recovery of cultural heritage. The European Union funds a program of international cooperation thanks to which students from seven countries can design innovative Augmented Reality applications to recover cultural heritage, promote tourism, and exchange these informations (see http://www.slideshare.net/xsune/googleglass-aumentame14?ref=http://www.aumenta.me/node?page=12).

6.4 University

Last but not least, research shows that Augmented Reality technology is and can be successfully applied in universities (Tampieri 2015). To give an example, Augmented Reality has a great potential to offer educational and realistic experiences to health sciences students, above all when it is not possible for them to practice in real contexts due to security, cost or viability reasons (Kamphuis et al. 2014, Zhu et al. 2014). Indeed, Augmented Reality technology has proven to be very effective in studying fields as important to medical training as anatomy (Thomas et al. 2010). Here are further applications of Augmented Reality technology to learning activities in higher education:

- Engineering students improved their visuospatial skills by analyzing abstract concepts through three-dimensional representations (Martín-Gutiérrez et al. 2010).
- Teacher training students learnt techniques to teach art through Augmented Reality technology (see https://www.youtube.com/watch?v=cC9UDkHWG3A&feature=youtu.be).

7. Conclusion

Although Augmented Reality technology was not initially designed with educational purposes, its applications on education are getting further relevance. Proof of this can be found in the diverse experiences and initiatives presented in this chapter for different educational stages and curricular areas. Unquestionably, Augmented Reality provides a blended learning experience that enriches reality with digital technology. This allows students not only to build broader

and deeper knowledge, but also become acquainted with their future works. After all, major companies are heavily investing in this technology to promote that employees work together in groups, develop a more meaningful learning and increase their motivation, among other things (Johnson et al. 2016). Since technological development progresses steadily and keeps producing devices that are increasingly cheaper and easier to handle, it is expected that Augmented Reality will acquire greater relevance in teaching-learning processes. However, we still cannot state that Augmented Reality has already been widely adopted in schools: in our opinion, at the very least two or three years will be needed for such implementation (Johnson et al. 2016).

References

Adell, Jordi/Castañeda, Linda (2012): "Tecnologías emergentes, ¿pedagogías emergentes?". In: José Hernández/Massimo Pennesi/Diego Sobrino/Azucena Vázquez (eds.), *Tendencias emergentes en educación con TIC*, Barcelona: Asociación Espiral, 13 – 32.

Billinghurst, Mark/Duenser, Andreas (2012): "Augmented Reality in the classroom". In: *Computer* 7, 56 – 63.

Bower, Matt/Howe, Cathie/McCredie, Nerida/Robinson, Austin/Grover, David (2014): "Augmented Reality in education – cases, places and potentials." In: *Educational Media International* 51(1), 1 – 15.

Chen, Chien-Hsu/Lee, I-Jui/Lin, Ling-Yi (2015): "Augmented Reality-based self-facial modeling to promote the emotional expression and social skills of adolescents with autism spectrum disorders." In: *Research in Developmental Disabilities* 36, 396 – 403.

Chen, Chien-Hsu/Lee, I-Jui/Lin, Ling-Yi (2016): "Augmented Reality-based video-modeling storybook of nonverbal facial cues for children with autism spectrum disorder to improve their perceptions and judgments of facial expressions and emotions." In: *Computers in Human Behavior* 55, 477 – 485.

Cheng, Kun-Hung/Tsai, Chin-Chung (2012): "Interactive Augmented Reality system for enhancing library instruction in elementary schools." In: *Computers & Education* 59, 638 – 652

Cheng, Kun-Hung/Tsai, Chin-Chung (2016): "The interaction of child-parent shared reading with an Augmented Reality (AR) picture book and parents' conceptions of AR learning: Child-parent shared Augmented Reality book reading." In: *British Journal of Educational Technology* 47(1), 203 – 222.

Chi, Hung-Lin/Kang, Shih-Chung/Wang, Xiangyu (2013): "Research trends and opportunities of Augmented Reality applications in architecture, engineering, and construction." In: *Automation in Construction* 33, 116 – 122.

Chicchi, Irene Alice/Pallavicini, Federica/Pedroli, Elisa/Serino, Silvia/Riva, Giuseppe (2015): "Augmented Reality: A brand new challenge for the assessment and treatment of psychological disorders." In: *Computational and Mathematical Methods in Medicine*, 2015, 1 – 12.

Cubillo, Joaquín/Martin, Sergio/Castro, Manuel/Boticki, Ivica (2015): "Preparing Augmented Reality learning content should be easy: UNED ARLE—an authoring tool for Augmented Reality learning environments." In: *Computer Applications in Engineering Education* 23 (5), 778 – 789.

De Pedro, Javier/Martínez, Carlos Luis (2012): "Realidad Aumentada: Una Alternativa Metodológica en la Educación Primaria Nicaragüense." In: *IEEE-RITA* 7(2), 102 – 108.

Dewey, John (1938): *Experience & Education*, New York: Kappa Delta Pi.

Di Serio, Angela/Ibáñez, María Blanca/Delgado, Carlos (2013): "Impact of an Augmented Reality system on students' motivation for a visual art course." In: *Computers & Education* 68, 586 – 596

Durlach, Nathaniel I./Mavor, Anne S. (eds.) (1995): *Virtual Reality: scientific and technological challenges*, Washington, D.C: National Academy Press.

Estopace, Eden (2015): "Augmented Reality apps for education win top prize in Philippine Hackaton." Open University (http://libezproxy.open.ac.uk/login?url=http://search.proquest.com.libezproxy.open.ac.uk/docview/1659810189?accountid=14697, visited on 28 February 2016).

Fombona, Javier/Pascual, María Ángeles/Madeira, María Filomena (2012): "Realidad Aumentada, una evolución de las aplicaciones de los dispositivos móviles." In: *Píxel-Bit. Revista de Medios y Educación* 41, 197 – 210.

Fundación Telefónica (2011): *Realidad aumentada: una nueva lente para ver el mundo*, Madrid: Fundación Telefónica.

García, Fernando (2014): "Fundamentos psicológicos de la realidad aumentada." In: *Revista Comunicación y Pedagogía* 277 – 278, 67 – 72

Huang, Yujia/Li, Hui/Fong, Ricci (2016): "Using Augmented Reality in early art education: a case study in Hong Kong kindergarten." In: *Early Child Development and Care* 186(6), 879 – 894.

Jabr, Ferris (2014): "Por qué el cerebro prefiere el papel." In: *Investigación y Ciencia* 449, 83 – 93.

Johnson, Larry/Adams Becker, Samantha/Cummins, Michele/Estrada, Victoria/Freeman, Alex/Hall, Courtney (2016): *NMC horizon report: 2016 higher education edition*, Austin, Texas: The New Media Consortium.

Johnson, Larry/Smith, Rachel S./Levine, Alan/Stone, Sonja (2011): *The 2011 horizon report*, Austin, Texas: The New Media Consortium.

Johnson, Larry/Smith, Rachel S./Levine, Alan/Stone, Sonja (2010): *The 2010 horizon report*, Austin, Texas: The New Media Consortium.

Johnson, Larry/Smith, Rachel S./Levine, Alan/Stone, Sonja (2006): *The 2006 horizon report*, Austin, Texas: The New Media Consortium.

Johnson, Larry/Smith, Rachel S./Levine, Alan/Stone, Sonja (2005): *The 2005 horizon report*, Austin, Texas: The New Media Consortium.

Kamphuis, Carolien/Barsom, Esther/Schijven, Marlies/Christoph, Noor (2014): "Augmented Reality in medical education?" In: *Perspectives on Medical Education* 3(4), 300 – 311.

Kerawalla, Lucinda/Luckin, Rosemary/Seljeflot, Simon/Woolard, Adrian (2006): "Making it real: exploring the potential of Augmented Reality for teaching primary school science." In: *Virtual Reality* 10(3 – 4), 163 – 174.

Kesim, Mehmet/Ozarslan, Yasin (2012): "Augmented Reality in education: Current technologies and the potential for education." In: *Procedia – Social and Behavioral Sciences* 47, 297 – 302.

Kilgus, Thomas/Heim, Eric/Haase, Sven/Prüfer, Sabine/Müller, Michael/Seitel, Alexander/Fangerau, Markus/Wiebe, Tamara/Iszatt, Justin/Schlemmer, Heinz-Peter/Hornegger, Joachim/Yen, Kathrin/Maier-Hein, Lena (2015): "Mobile markerless Augmented Reality and its application in forensic medicine." In: *International Journal of Computer Assisted Radiology and Surgery* 10(5), 573 – 586.

Klopfer, Eric/Sheldon, Josh (2010): "Augmenting your own reality: Student authoring of science-based Augmented Reality games." In: *New Directions for Youth Development* 128, 85 – 94.

Lee, Kangdon (2012): "Augmented Reality in Education and Training." In: *Techtrends: Linking Research & Practice To Improve Learning* 56(2), 13 – 21.

Lin, Chien Yu/Chang, Yu Ming (2015): "Interactive Augmented Reality using Scratch 2.0 to improve physical activities for children with developmental disabilities." In: *Research in Developmental Disabilities* 37, 1 – 8.

Martín-Gutiérrez, Jorge/Luís Saorín, José/Contero, Manuel/Alcañiz, Mariano/Pérez-López, David C./Ortega, Mario (2010): "Design and validation of an augmented book for spatial abilities development in engineering students." In: *Computers & Graphics* 34(1), 77 – 91.

Martin, Sergio/Díaz, Gabriel/Sancristobal, Elio/Gil, Rosario/Castro, Manuel/Peire, Juan (2011): "New technology trends in education: Seven years of forecasts and convergence." In: *Computers & Education* 57(3), 1893 – 1906.

Milgram, Paul/Takemura, Haruo/Utsumi, Akira/Kishino, Fumio (1994): "Augmented Reality: a class of displays on the reality-virtuality continuum". In: *Proceedings the SPIE: Telemanipulator and Telepresence Technologies*, 2351, 282 – 292.

Moore, Jeoffrey. A (2015): *Cruzando el abismo*, Barcelona: Planeta.

Muñoz, Juan Miguel (2014): "Realidad Aumentada, una oportunidad para la nueva educación." In: *Revista Comunicación y Pedagogía* 277 – 278, 6 – 11.

Nincarean, Danakorn/Alia, Mohamad B./Halim, Noor D. A./Rahman, Mohd H. A. (2013): "Mobile Augmented Reality: The potential for education." In: *Procedia – Social and Behavioral Sciences* 103, 657 – 664.

Prendes, Carlos (2015): "Realidad Aumentada y educación: análisis de experiencias prácticas." In: *Píxel-Bit* 46, 187 – 203.

Research and Markets (2015): "Global Augmented Reality for mobile devices 2015: Gaming and entertainment, marketing and advertising, information, education and toys, retail and e-commerce, and industrial applications." In: *Business Wire*, 20 March 2015. http://libezproxy.open.ac.uk/login?url=http://search.proquest.com.libezproxy.open.ac.uk/docview/1664738326?accountid=14697, visited on 29 February 2016.

Roscorla, Tanya (2013): "Augmented reality meets music education." In: *McClatchy – Tribune Business News*, 22 August 2013. http://libezproxy.open.ac.uk/login?url=http://search.proquest.com.libezproxy.open.ac.uk/docview/1427327809?accountid=14697, visited on 29 February 2016.

Sheehy, Kieron/Ferguson, Rebecca/Clough, Gill (2014): *Augmented education: Bringing real and virtual learning together*, New York: Palgrave Macmillan.

Sommerauer, Peter/Müller, Oliver (2014): "Augmented Reality in informal learning environments: A field experiment in a mathematics exhibition." In: *Computers & Education* 79, 59 – 68

Tampieri, Laura (2015): "Innovating the didactical methodologies applied in universities through Second Life and Practice Firm: case study". In: *Technology, Innovation and Education* 1(1).

Thomas, Rhys G./John, Nigel W./Delieuc, John M. (2010): "Augmented Reality for anatomical education." In: *Journal of Visual Communication in Medicine* 33(1), 6 – 15.

Tomi, Azfar B./Rambli, Dayang R. A. (2013): "An interactive mobile Augmented Reality magical play-book: Learning number with the thirsty crow." In: *Procedia Computer Science* 25, 123 – 130.

Wei, Xiaodong/Weng, Dongdong/Liu, Yue/Wang, Yongtian (2015): "Teaching based on Augmented Reality for a technical creative design course." In: *Computers & Education* 79, 59 – 68.

Wu, Hsin-Kai/Lee, Silvia/Chang, Hsin-Yi/Liang, Jyh-Chong (2013): "Current status, opportunities and challenges of Augmented Reality in education." In: *Computers & Education* 62, 41 – 49.

Yilmaz, Rabia (2016): "Educational magic toys developed with Augmented Reality technology for early childhood education." In: *Computers in Human Behavior* 54, 240 – 248.

Zhang, Jia/Sung, Yao-Ting/Houc, Huei-Tse/Chang, Kuo-En (2014): "The development and evaluation of an Augmented Reality-based armillary sphere for astronomical observation instruction." In: *Computers & Education* 73, 178 – 188.

Zhu, Egui/Hadadgar, Arash/Masiello, Italo/Zary, Nabil (2014): "Augmented Reality in healthcare education: an integrative review." In: *PeerJ* 2, e469.