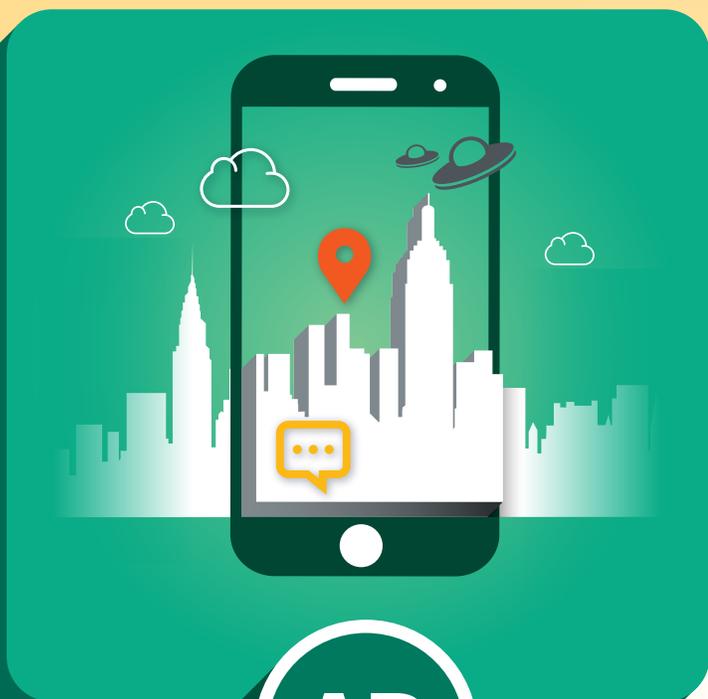
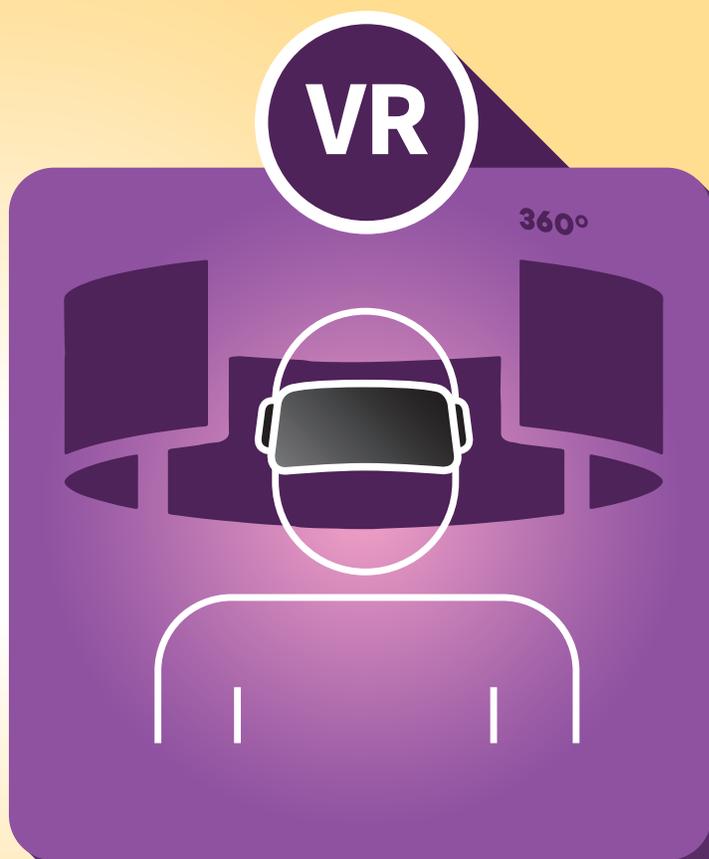


# Edu Trends

MAR 2018



AR



# Augmented and Virtual Reality

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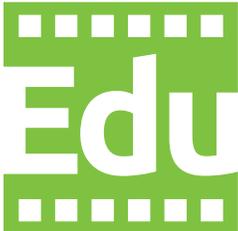


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# Introduction

**This Edu Trends offers a broad overview of the role Augmented Reality and Virtual Reality play in the international educational arena. The adoption and integration of these technologies translate into endless possibilities for innovation in our teaching practice, as we will see in this report.**



Before taking a closer look at what we now call Augmented Reality and Virtual Reality, it is important to mention that there are diverse immersive technologies that offer different ways of combining the digital world with reality at several levels of immersion. In fact, keeping track of all the terms that describe immersive technological experience can be quite complex, since there is such a wide variety of options.

We will briefly explore the possibilities offered by immersive technologies, starting with the 360-degree video we can obtain with a video camera, which captures everything that is happening around us, providing excellent material to be used on a virtual reality platform. In turn, virtual reality is a totally immersive experience that presents a completely new world around us which can be accessed using special goggles, visors or headsets.

Augmented reality is a technology that overlays computer-generated images onto a view of the real world. It requires the use of a mobile device, such as a smartphone, tablet, goggles or visors. Meanwhile, mixed reality is a sub-category of augmented reality that integrates 3D imagery into your view of the environment (Pixvana, 2017).

As can be seen, there is a wide variety of immersive technologies or “realities”. The recently introduced concept of Extended Reality (XR) is an umbrella term that encapsulates augmented reality (AR), virtual reality (VR), mixed reality (MR) and any others that might emerge with technological advancements related to the same concept (Qualcomm Technologies, Inc., 2017).

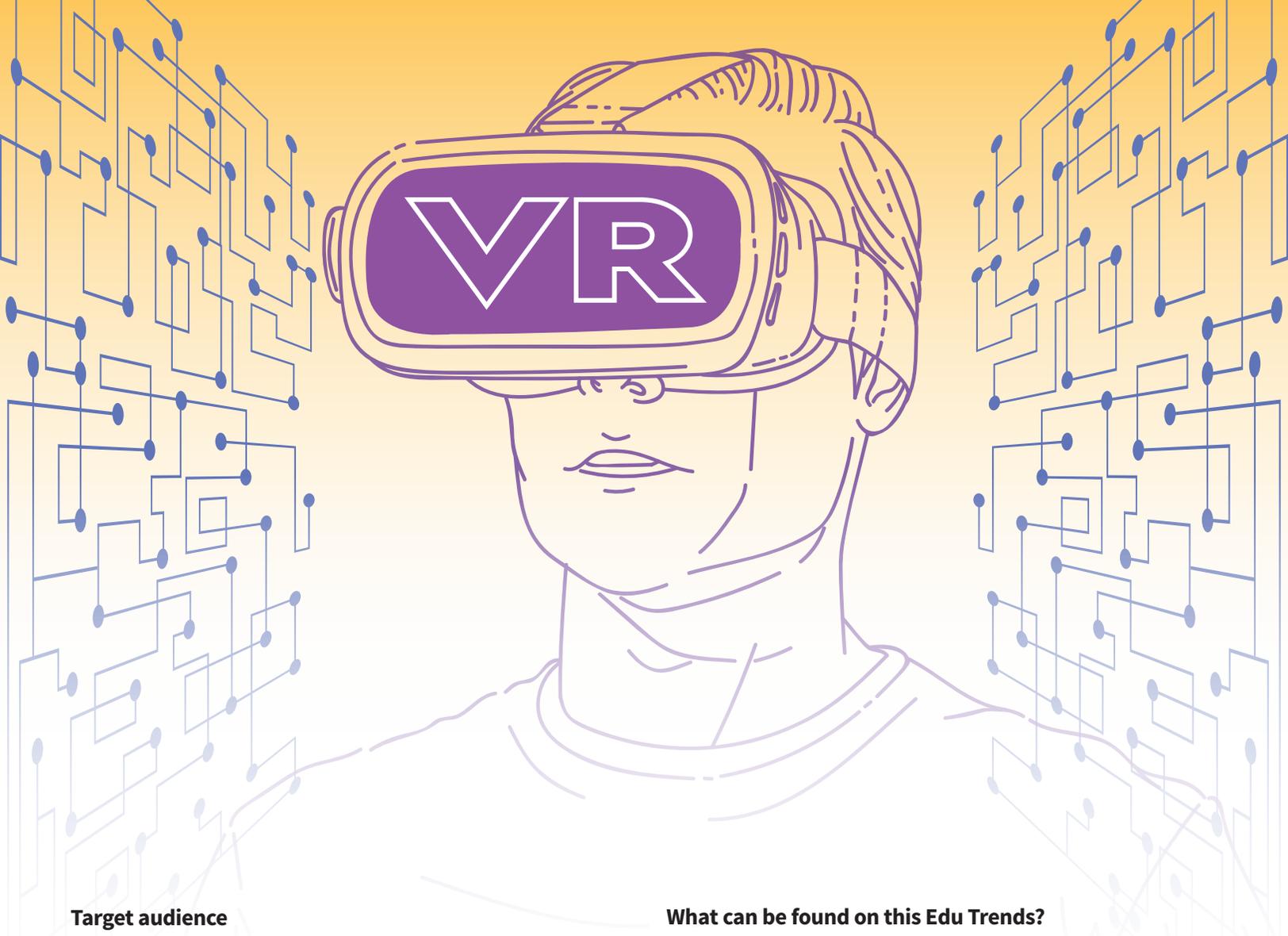
The need to understand and explain how we can interact in a real space and a virtual space is nothing new. Paul Milgram and Fumio Kishino (1994) coined the term Virtuality Continuum, where they explain the concept of mixed reality, which is the interaction between a real environment and a virtual environment at different levels.

The use of the concepts of Augmented Reality and Virtual Reality is becoming increasingly common in the field of education, as can be seen in the prestigious Horizon Report (Johnson et al., 2016), which describes the most relevant global educational trends for the near future. This report indicated that both technologies will be key components in the future of education, growing exponentially over three years.

In 2016, Augmented Reality (AR) was no longer a trendy term used by technology geeks but became part of everyday conversations across the planet. The Pokémon Go game application converted green areas, plazas and shopping centers in large cities into theme parks where people could play and connect with other players (Marín, 2016).

In the same year, large technology companies launched on the market their Virtual Reality (VR) devices: Facebook redesigned the Oculus Rift- headset, Google opted for Daydream as the VR platform for smartphones and Sony launched the VR PlayStation with VR goggles.

Even though the implementation of these trends is very recent within the educational system, their positive effects on learning have already been established. However, this is still in the exploratory stage and there are more doubts than certainties. How are AR and VR being applied in education? What are the implications of these resources for the way an educator teaches? What impact do they have on learning and how can it be assessed? What are the challenges of making them fundamental resources in education? Giving simple answers to these questions is the objective of this Edu Trends.



### Target audience

- Faculty in general who wish to narrow the digital gap with their students through the use of technological resources that motivate them and foster meaningful learning.
- Online course designers and instructors, seeking learning resources and models mediated by technology.
- Entrepreneurs in the educational innovation sector.
- Digital educational resource developers.
- Educational publishers and organizations who are exploring the potential of AR and VR as learning resources.
- Anyone interested in technological and pedagogical transformations that play a leading role in the present and break new ground for the future of education.

### What can be found on this Edu Trends?

- A brief history of the recent evolution of AR and VR.
- A proposal for defining and differentiating both concepts.
- Recommendations for constructing a pedagogy based on these resources: the role of the professor, teaching techniques and assessment strategies.
- Cases of the application of AR and VR at Tec de Monterrey.
- Cases of the application of AR and VR at different universities worldwide and for diverse academic areas.
- Critical assessment of the main benefits and challenges of AR and VR in education.
- Predictions about the future of AR and VR.

# Definition of Key terms

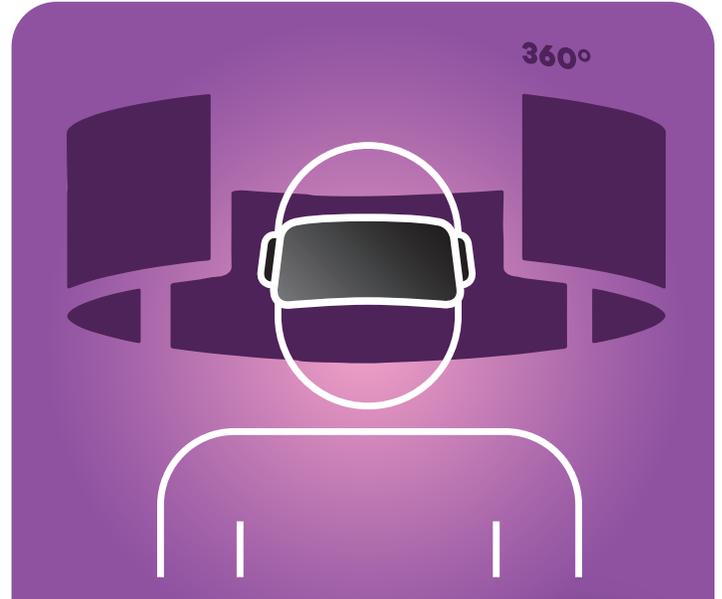
## What is the difference between AR and VR?



**Augmented Reality**

A technology that adds digital information to physical elements in the environment, real images or objects captured through a mobile device.

**AR**



**Virtual Reality**

Entails immersion in the digital simulation of a world in which users can manipulate objects and interact with the environment.

**VR**

**MR**

**Mixed Reality**

A combination of AR and VR: users perceive the real environment surrounding them (through goggles, for example) on which a digital environment is projected.

**IoT**

**Internet of things**

A set of objects with sensors or chips that interact with the real world.

**Table 1.** Comparison of the definitions of AR, VR, MR and IT

	AR	VR	MR	IoT
Criterion				
User interaction with natural reality	<b>High</b> Interaction is with the real world based on the digital information added to the same	<b>Low</b> Users are isolated from reality and submerged by means of a device in a fully digital sensorial universe	<b>Medium</b> The real world serves as a scenario for projecting virtual reality, in which users are immersed by means of a device	<b>Low</b> Users are consumers of the information or performance of things
Level of immersion in a digital experience	<b>Medium</b> Depends on the digital density added to reality	<b>High</b> Implies a complete immersion in a fully digitalized parallel reality	<b>High</b> The real world is replaced by a sensorial experience immersed in a virtual world	<b>Low</b> Users are in real environments, although they can connect with objects in the cloud
Emblematic device	Apps in Smart Phones Equipped with AR (e.g. Pokémon Go)	Sensorial headsets (e.g. Oculus Rift)	Goggles that project digital information on a real environment (e.g. HoloLens)	Refrigerator with the capacity to offer information on food expiry date or recommend recipes
Representative company in the development of the technology	Google	Facebook	Microsoft	Cisco
Development phase	In expansive exploration	Readjustment, after the initial bubble	In experimental revolution	Immediate commercial boom

**“ Augmented Reality is flourishing in productive and industrial environments. This technology has proven to be a highly effective technique for transferring procedural knowledge. This makes it an invaluable aid for repair or maintenance training processes”**

Eduardo González Mendivil

# AR

# Timeline

## RECENT ARCHAEOLOGY

1901



### Literary background:

**Frank Baum**, the children's author (Wizard of Oz) publishes *The Master Key*, in which the protagonist is a little boy who, with his glasses, can see people's moral qualities.

1957



### Background:

**Morton Heilig** creates the **Sensorama** prototype, a machine that adds sensorial experiences (sound, 3D images, aromas, air) for moviegoers.

1968



### First device:

**Ivan Sutherland** invents the **HMD**, a device that projects geometric graphics onto the surrounding environment.

1990



### Origin of the term:

The term is coined by **Tom Caudell**, an engineer at **Boeing**, who developed some goggles that project wiring plans, as a virtual guide, to train the aerospace company's electricians.

# KEY DEVICES AND APPLICATIONS (21<sup>st</sup> c.)

2000



## ARQuake

First videogame device with AR.

2008



## AR Wikitude

AR device with geolocation.

2009



## ARToolkit

Open-source platform for generating AR content.

2012



## Glass

Google AR goggles.

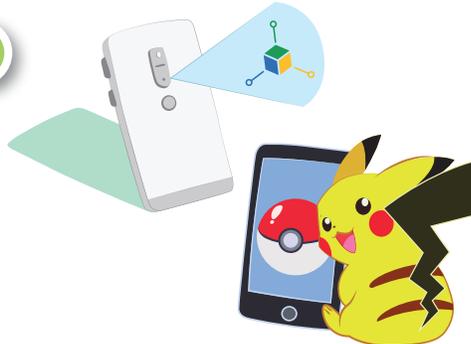
2015



## Proyecto Tango

3D AR technology for smartphones.

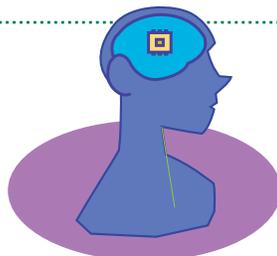
2016



Launch of **Lenovo Phab Pro (Google)**  
First AR-enabled mobile device.

Niantic launches **Pokémon Go.**

2017



Launch of **Neuralink**  
**Elon Musk's** project to connect AR in the human brain.



# Timeline

## RECENT ARCHAEOLOGY

1840



**Background:**

The **stereoscope**, invented by **Charles Wheatstone**, consisted of binoculars which, through a set of mirrors and two photographs of the same scene, created a basic impression of three-dimensionality.

1929



**First device:**

For the first time, the **Link Trainer** is used to provide virtual training for US military pilots.

1935



**Literary background:**

In his novel “Pygmalion’s Spectacles”, science fiction writer, **Stanley G. Weinbaum**, describes a pair of goggles that enabled holograms of human experiences, including smell and touch.

1965



**Origin of the term:**

**Ivan Sutherland** defines the concept in a newspaper article with the title “The Ultimate Display”, although it was **Jaron Lanier** who popularized the term.

## KEY DEVICES AND APPLICATIONS

1980



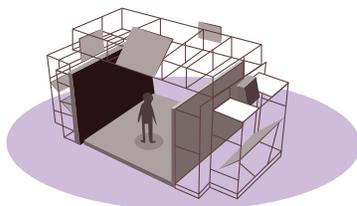
**Stereographics** creates the first virtual vision goggles.

1982



**Thomas Zimmerman** creates the **data glove** to control virtual instruments by hand.

1991



**CAVE**  
The first immersive VR room.



**Virtuality**  
The first multi-user VR videogame.

2015



**HoloLens**  
**Microsoft** goggles that combine VR and AR.

2016



**Oculus Rift**  
The mass-market VR headset financed by **Facebook**.

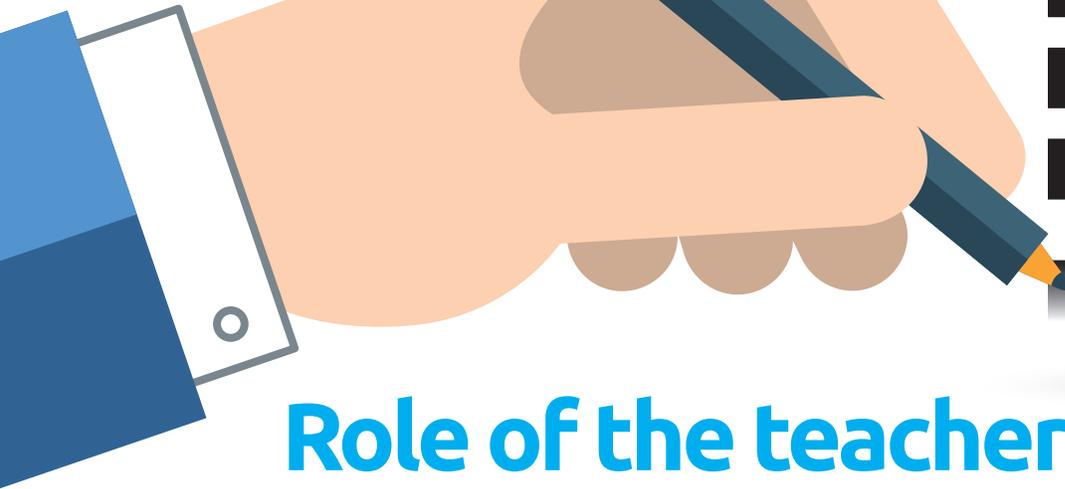


**Daydream**  
**Google's** VR platform.



**PlayStation VR**  
First game console mass-market VR headset.

CREATOR ADVISOR TRANSMITTER  
MENTOR EXPLORER DESIGNER  
INNOVATOR THINKER



## Role of the teacher

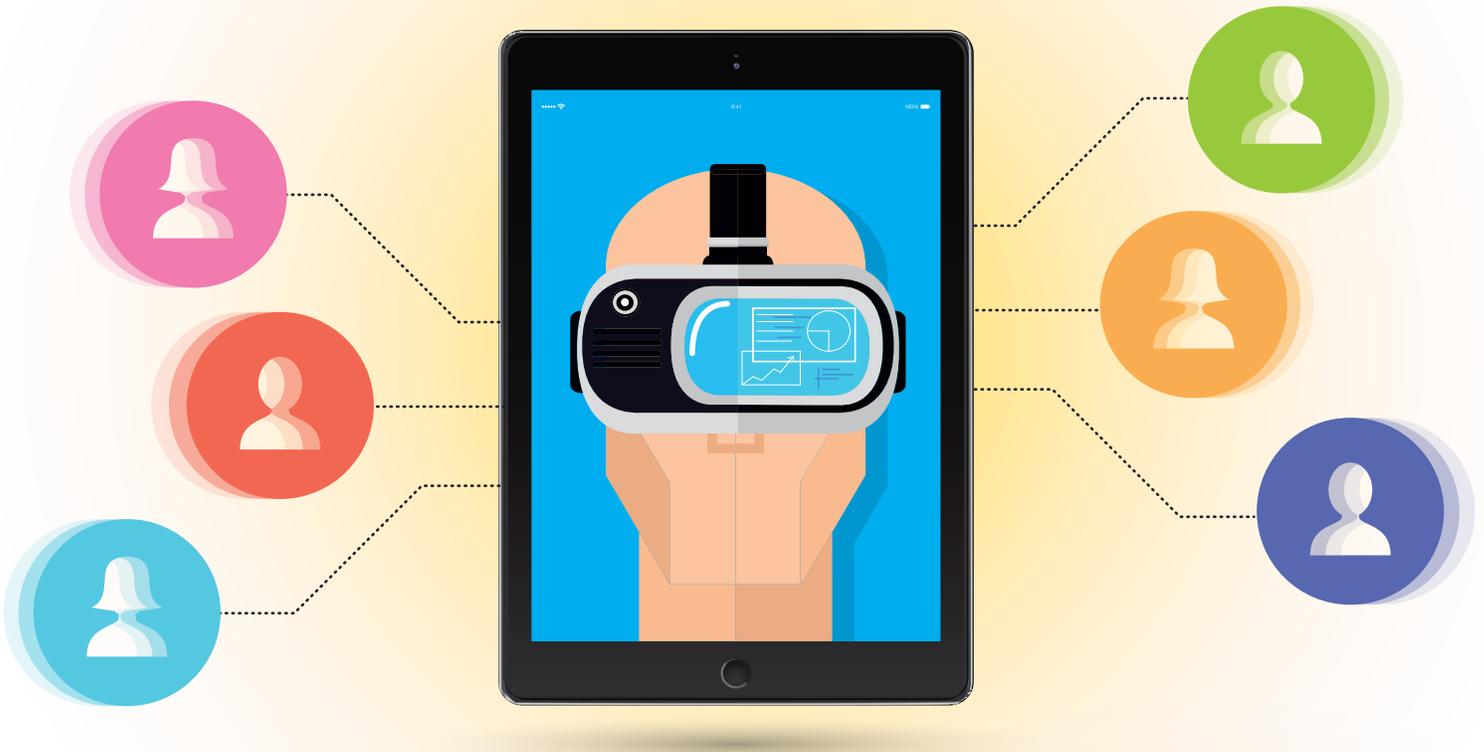
Both AR and VR imply powerful sources of knowledge and learning environments that, inevitably, displace the teacher as the protagonist in education.

Will the growing digitalization of learning content and resources leave millions of teachers out of work? Actually, the implementation of these resources in education requires the participation of professionals who will guide the development of applications, design learning experiences, advise students in their interaction with these objects, and, finally, evaluate and provide feedback on learning outcomes. Therefore, it requires teachers to take on roles other than those implemented in a conventional lecture, including, in particular, the following:

- **Creator** of digital learning resources, in collaboration with digital production specialists (programmers, editors, designers, animators, etc.).
- **Advisor** in pedagogical matters, to solve students' doubts and problems regarding interaction with resources.
- **Transmitter** and builder of knowledge, to offer a broader information framework (theory) applied to activities with AR or VR.
- **Mentor**, to guide, encourage, accompany and challenge students in their use of technology.
- **Explorer** and curator of resources, to find and filter the best resources available in the market for specific learning purposes and provide them to the student.
- **Designer**, instructional designer, to build stimulating learning activities using AR and VR.
- **Innovator**, to develop emerging educational possibilities for these technologies, forming new learning practices.
- **Thinker**, critical thinker to advise on the risks of knowledge commercialization, drive collaboration, promote ethical principles in actions, or connect very different fields of knowledge.

# Pedagogical principles of AR and VR

The sensorial spectacularity of AR and VR does not, in itself, generate learning. For this to happen, within an educational system, the technological resources must be part of an activity whose design is the responsibility of the educator. How can we make the most of these resources? What pedagogical principles can guide the efforts of those who lead this learning experience?



On the one hand, AR and VR are often used as specific resources for traditional instructional practices (Hanson and Shelton, 2008). The main value of AR and VR in these cases is to increase students' motivation and enrich the learning resources.

However, from a contemporary sociocultural perspective, the current technological revolution also requires a revolution in the field of education with a deeper transformation in teaching-learning practices and not just in educational materials. Lankshear and Knobel (2008) affirm that educators run the risk of offering "old wine in new bottles". Therefore, there is a need for "emergent pedagogies" (Adell and Castañeda, 2012) that will successfully explore the possibilities of fomenting new technologies.

Emergent pedagogies are "the set of pedagogical approaches and ideas that emerge from the use of ICT in education and endeavor to take advantage of all their communication, information, collaborative, interactive, creative and innovative potential within a framework of a new learning culture" (Adell and Castañeda, 2013: p. 15).

In the concrete case of AR and VR, the lessons learned from their educational application indicate that the best practices respond to a pedagogical approach with a constructivist legacy, oriented toward learning by doing, since the students decide how to combine augmented information or how to interact with virtual simulation. Therefore, the student's relationship with the learning goal is not based solely on consulting intellectual content, but it also implies an experience of immersion in the learning environment.

## Outstanding pedagogical trends:

### Digital educational materials

An increasingly popular trend is the evolution of traditional reading and writing materials that support learning (books, photocopies, etc.) toward a new ecosystem of digital resources. The best example of AR consists of “magic books”, which are texts with markers that activate the display of added information in 3D by means of a digital device. The growing availability of VR-based videogames also implies a revolution in the materials offered in order to participate in an immersion experience and not just look up information.

### Gamification

The capacity of games to generate learning is one of the expanding educational trends. The advantage of VR is the impression of total immersion in the game, while AR contributes the capacity to transform any real scenario on a game board. This is possible, not only in applications designed specifically as games, but also in those that incorporate game dynamics (collaborative or competitive) in a “serious” learning environment. For example, gymkhanas, in which students follow a series of clues or manage to progress through several levels is one of the most frequently used trends for these technologies (Fundación Telefónica, 2011).

### Experiment-based learning

Both AR and VR enable scenarios in which students can test the theory learned about certain types of content, exploring the conditions in which they do or do not apply (Wojciechowski and Cellary, 2013). These digital technologies make it possible, at a relatively low cost, to introduce students to the reality to be studied through cases that would otherwise be impossible to approach, such as: historical scenarios; or expensive contexts, such as pilot training which are substituted by flight simulations; or extremely risky situations, such as medical manipulation of sick bodies.

### Mobile learning

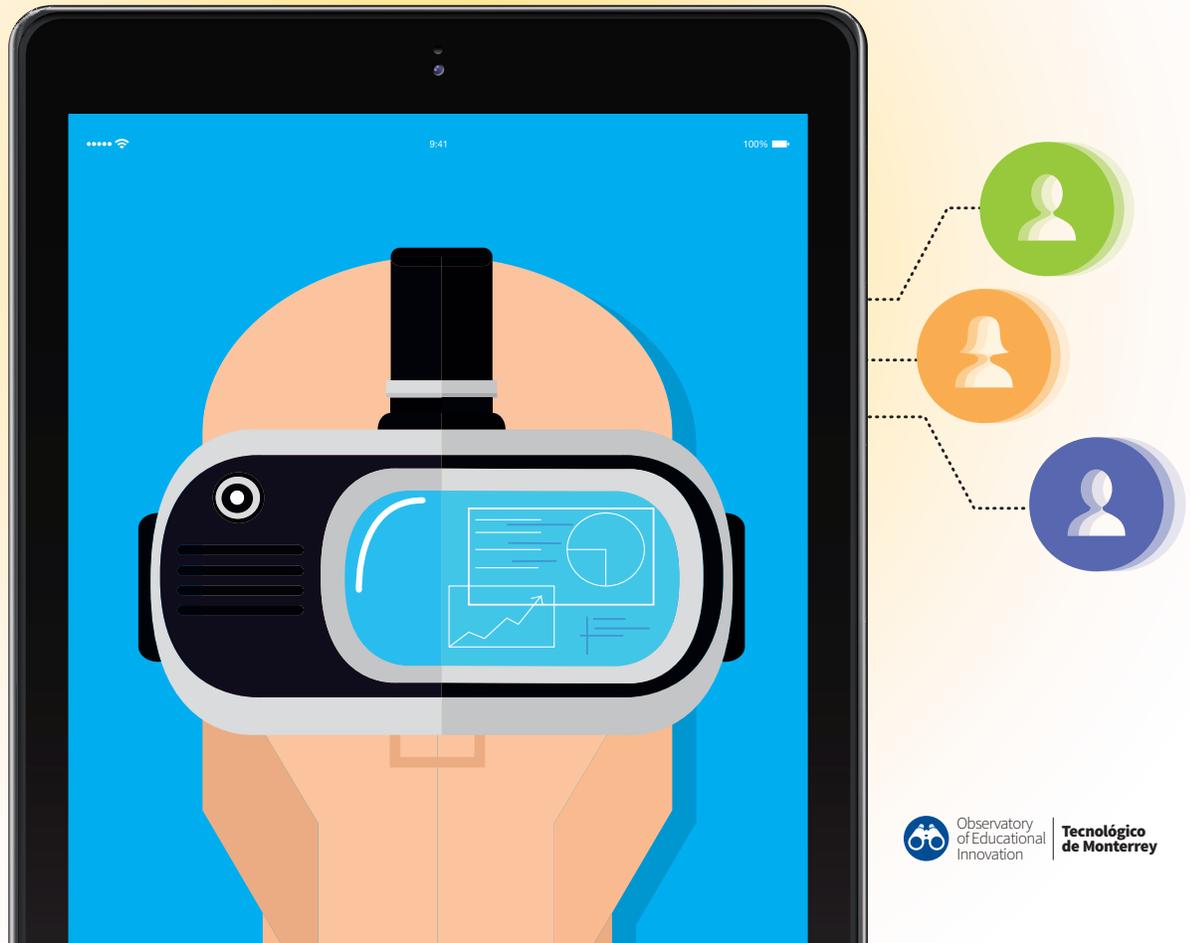
Students can explore the AR- or VR-based learning content in any order, whenever and wherever they wish, without being restricted by class schedules and the classroom, as long as they have the appropriate digital device. It offers the advantage (and the challenge) that anywhere can become a learning scenario and the activity can be designed in the most suitable simulated or real environment for its development (Redondo et al., 2012).

### Blended learning

One of the criticisms of the intensive use of learning is, precisely, the absence of a pedagogical plan, which integrates the resources offered by AR and VR within a sequence designed specifically for the development of competencies. This is why some authors prefer a blended model that combines the virtues of face-to-face learning (physical presence of a teacher, performance assessment, feedback from an expert) with those of online learning (Cadavieco and Pascual, 2017).

### Expanded education

In the broadest sense, the disruptive nature of AR and VR lies in their capacity to generate learning environments with the person who is learning as the protagonist, without the need for a specific program of study or the guidance of a teacher, according to the advocates of the concept of expanded education (Díaz and Freire, 2012). The platforms that offer tools for developing digital applications allow individuals to co-design their own learning experiences in social innovation laboratories.



# Assessment

In some cases, Virtual Reality and Augmented Reality join the bank of materials used within traditional pedagogy. Nevertheless, their disruptive potential is enormous and makes it possible to explore ways of designing and learning that are emerging with great strength in the digital era. We need to move out of our comfort zone of the usual assessment instruments and explore strategies that better match the learning experience generated by these technologies.

## ASSESSMENT PRACTICES FOR VR AND AR



### Gamification

This is the most prominent pedagogical trend in the use of AR and VR and offers assessment tools that add an extra dose of motivation. Gymkhanas, competitions, bonuses, leveling up or any dynamic taken from the game world that can be channeled toward increasing individual competitiveness or team cooperation.



### Automatic feedback

Assessment can be integrated into the VR videogame itself or into the added AR information. In the case of VR, “levels” of difficulty are frequently used and can be accessed progressively after having overcome tests in the previous level. The advantage of this tool is the immediacy of the response, which implies a powerful reinforcement for the acquisition of content or the development of the desired competencies.



### Problem-based Learning (PBL)

Both VR and AR integrate learning content within a relevant scenario (real or simulated). One way of taking advantage of this is by articulating the learning experience around the solution of problems. Gymkhanas, for example, are typical assessment practices in geolocated VR or AR environments.



### Portfolios

In student-centered education, VR and AR users can choose how to demonstrate their evolution. Therefore, the construction of portfolios, especially digital portfolios, is a useful tool that helps each individual to reflect on their learning and defend it with the most appropriate pieces of evidence. The most notable evidence consists of blogs, electronic files (on Drive or Dropbox, for example) or products derived from the application in real contexts (mock-ups, devices, maps, etc.) of the knowledge acquired.



### Self-assessment

Student-centered learning uses a congruent assessment strategy in which students themselves self-regulate their performance. The teacher’s role is to provide students with self-assessment rubrics or instruments so that they can appreciate the extent to which they are aware of their achievements and their areas of opportunity, using VR and AR tools.



### Co-assessment

In collaborative activities based on VR and AR, students have the opportunity to work in a team in support of a common objective. An assessment strategy for this learning among peers is the co-evaluation of their respective contributions through a rubric offered by the teacher, which can serve to generate awareness of the most relevant aspects implied in the learning process.

# Benefits

The novelty of using AR and VR in education generates expectations that must be confirmed and questioned in practice. Beyond the particularities of the two technological modalities, the literature reports in both cases similar benefits for learning, which is why this section does not deal with them separately. However, it is important to emphasize that the use of these tools to obtain positive effects automatically in educational processes is not sufficient, although employing both resources has repeatedly proved to be worthwhile in the educational context.



## Attention

A natural effect of the sensorial wealth of AR and VR and their capacity to generate an immediate response to the subject's action or their immersive nature is to reinforce the attention of the person who is using these technologies. This benefit is crucial in a digital era in which, as Nicholas Carr (2010) stated, overstimulation is weakening our capacity to pay attention.



## Memory

In the short term, with the use of VR and AR, the memory receives the seal of the information content that is situated in the context in which the person interacts. In the long term, their use improves the subject's capacity to retrieve an experience "lived" and not just learned instrumentally.



## Efficient learning pace

They shorten the time for acquiring certain skills, especially procedural ones in which the manipulation of digital entities within a VR experience or the interaction with a real environment with AR make it possible to accelerate the practice of these operations (Redondo et al., 2012).



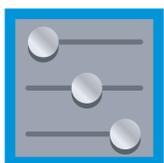
## Practical experience of theory

They facilitate cognitive development derived from the possibility of experiencing on the basis of refuting or confirming a theory; interaction with the learning objective; the generation of alternatives and new ideas; and the visualization of the object from diverse angles or points of view. In short, VR and AR promote the materialization of the learning process, the immersion of the learner in a context of more tangible information that makes it possible to intensify the relationships between theory and practical application.



## Positive effect on motivation

Different studies have indicated the impact of using VR and AR to motivate learning. On the one hand, they increase the value of acquiring certain skills within a context of immersion, in which the students are the protagonists. On the other, they facilitate the impression of undergoing an innovative experience with a highly sensorial impact, which generates curiosity and is especially attractive for the generations who have grown up in environments that are increasingly dominated by digital technology.

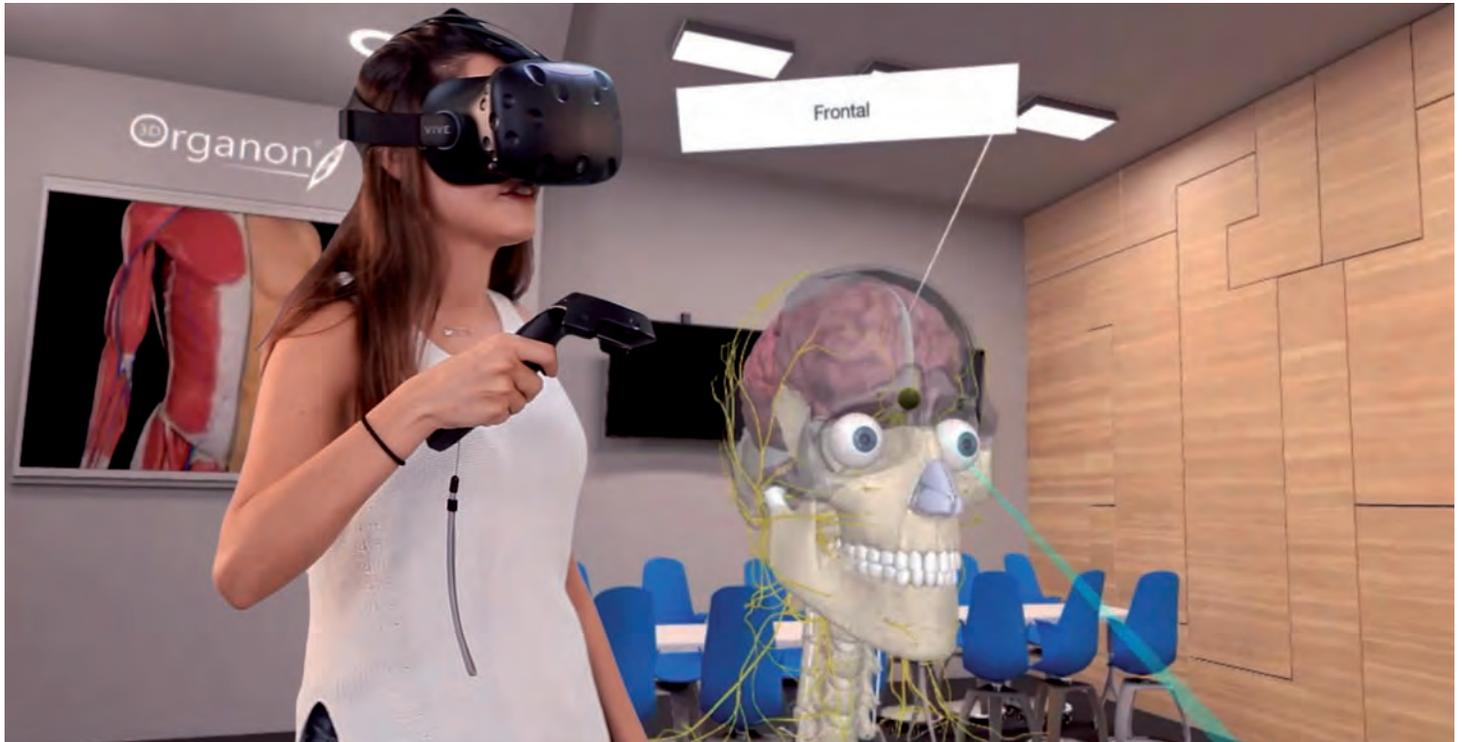


## Learning personalization

The capacity of AR and VR to generate a different type of dense information around the learning content makes it possible to individualize the learning experience and adapt it to different cognitive styles and ways of learning. For example, they have been combined with adaptive e-learning platforms so that students, by virtue of their performance in the course activities and the difficulties they have in resolving them, can use different technological support resources (Fabregat, 2012).

# Relevance for Tecnológico de Monterrey

In the context of Tecnológico de Monterrey, the use of Augmented Reality and Virtual Reality offers students the possibility of benefiting from moments that improve their educational experience, through an introduction to up-to-date information, using digital elements that facilitate interaction with situations that are characteristically difficult to access in real contexts.



Current technologies should be incorporated as instruments or means to improve the teaching-learning processes, since, on the one hand, students today are more active, they always need to see, use and be surrounded by technology and, on the other, the teacher must have the capacity to capture their attention and engage them actively in their learning.

In a world in which the combination of the virtual and the real is increasingly imminent, geolocation, mobile telephony and games are concepts and technologies that must necessarily be addressed in an institution in order to optimize the degree of student learning. The latter is fostered because AR and VR support the increase in individuals' attention, enabling them to develop knowledge as if they were in the scene of the events. In this way, the theory students learn in the classroom is complemented in practice.

At present, AR and VR are known to drive the skills of the current generations -digital natives- and improve the development of the competencies required of Tecnológico de Monterrey graduates in the workplace, through challenging experiences in educational spaces that are highly interesting and require a great deal of interaction. Therefore, at the institution, the process for adopting immersive technologies in education is in its initial stage, thus offering enormous potential to exploit them and generate the expectation of having an impact on students while they are still young enough to feel amazement.

# Relevant cases at Tecnológico de Monterrey



The audio was hosted on the open-source page Soundcloud. Given the nature of the app, as soon as the painting or work is scanned, the audio commentary begins automatically. This means that any of the exhibition attendees could go up to the work and listen to explanation even if the exhibitor was not present. A total of about 1,200 scans were executed, which is 50% more than the in-person attendees.

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Augmented Reality was implemented in the course Artistic and Literary Interpretation at the Campus Estado de México High School. The course covers the different periods of art history. One of the main objectives of this tour is for students to generate their art portfolio, in relation to works, styles, authors and periods, and also for them to be able to understand the social and personal processes that gave rise to these works. By the end of the course, they will be able to recognize and interpret art in general.

A template similar to a “World Cup stamp album” was created in which black and white pictures of diverse works of art were placed. These pieces covered the different art periods, from Prehistory to Postmodernity.

The templates were then printed with all the images obtained. Some of them were uploaded to the Aurasma platform, where videos were shown together with links to further information on the work of art in question. They were distributed in class as part of a stamp economy, thus generating a gamification-style dynamic, with the ultimate purpose of filling up the album. Students had to scan the images to find the “hidden message or capacity”, the image that would trigger augmented reality. While motivating the class with the album dynamic, identification, familiarization and a cultural archive were being generated in students.

This project increased students’ capacity to identify works and artists with their corresponding artistic period. It also increased student participation, as after working to obtain the stamps, they appreciated them sufficiently to want to find out more about them, eagerly scanning their images to discover what their colors should be, who created them, how and why.

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The Art and Culture course promotes art awareness. Students attend a workshop where they produce artwork that will be exhibited at the end of the course. As part of the final project, the artworks created during the semester are exhibited together with a commentary on the creation process, the artist’s intention and the content of the same.

Approximately 750 students from the Campus Estado de México High School participated in this exhibition. Owing to the students’ academic commitments and ensuring that everyone would have the opportunity to exhibit, it was decided to integrate Augmented Reality into the execution of the project. Each of the pieces was included in a library of images created in the Layar application and, subsequently, the audio corresponding to the works executed by each student were uploaded.

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In order to foment meaningful content learning in the academic program Climate Change and Energy Use, participative debate spaces were generated to select content related to the course subject matter and identify the scenarios to be augmented using real-world objects. The tool Blender was used to design the educational resources provided by Augmented Reality, adding mobile-device compatibility and thus enabling the possibility of being scaled up to web platforms in the future. Once the application had been developed, it was installed in 24 devices to be used in the Media Scape LearnLab (MSLL) classrooms.

The dynamic was executed in four teams with six students each; the activity was timed and required all the team members to work to reach the goal within the estimated time (five minutes). Cards were used and, on activating the first one through the smartphone camera, a city appeared. On activating the other cards, environmental problems were reflected on the first one. The students observed the issues and proposed the respective solutions by activating the cards. With this methodology, students designed a clean city, free from atmospheric pollutants in the soil, water and air, and promoted the use of clean energy in the city.

The results obtained indicate that Augmented Reality influences students' behavior, increasing their interest and level of learning. Students are capable of proposing solutions to environmental issues and of making decisions that favor sustainable development and quality of life. They are more aware of the consequences of anthropogenic activities on climate change and land ecosystems, and of the current high levels of atmospheric pollution affecting the mobility and health of numerous inhabitants. Augmented Reality possesses the capacity to enrich elements of reality with detailed information. Working in 3D generates a heightened interest in young people and the facility to manipulate virtual objects with the body and without the need to use a mediating object, such as a keyboard or mouse.

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 León

In the course Digital Expression, offered in the second semester of high school, we have used Augmented Reality in the final project to integrate the content of this course with that of the course Spanish Language, Art and Literature, which seeks to create a virtual museum to show the most relevant characteristics of a Mesoamerican culture using Aurasma. The Spanish language teachers were in charge of establishing and checking that the content was appropriate according to the assigned topic and the Digital Expression students designed images that would function as triggers, while the auras consisted of videos that explained the political, economic and social aspects, narrated a legend with the students as the actors, and also included a video with the stop-motion technique in the reconstruction of an architectural piece.

For the final presentation, the montage was implemented in the high school classrooms to represent the virtual museum. Each of the teams offered visitors telephones and tablets so they could "read" the images they had created and listen to each of the related videos. The entire campus community and parents were invited to this exhibition. The results of this project were highly satisfactory. The fact that students were able to compile and assess information on different Mesoamerican cultures and, by selecting the best multimedia resource to display it, made visitors interact in an innovative, interactive, attractive and didactic manner with the objects exhibited, ensuring that they obtained detailed information on each of the works.

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In this project, students enrolled in the Digital Expression course selected someone from the campus community (students, faculty, coaches, administrative staff) whom they admired and, by means of the storytelling technique, they told the selected person's story.

Using Augmented Reality, students were asked to design the image that would serve as a trigger, showing the qualities that made them select it, and apply the topics seen in class related to image edition. For the video, the challenge was to express and transmit emotions, and for the people who watched the videos on activating the trigger to be able to connect it to the story being told.

One of the outcomes of this project was that students were able to offer a public acknowledgement of their heroes at the campus, since the presentation took place in the main auditorium where students placed their posters (triggers) and all the attendees could play the video on their phone or tablet and discover other (little known) aspects about the people who comprise the Campus León community.

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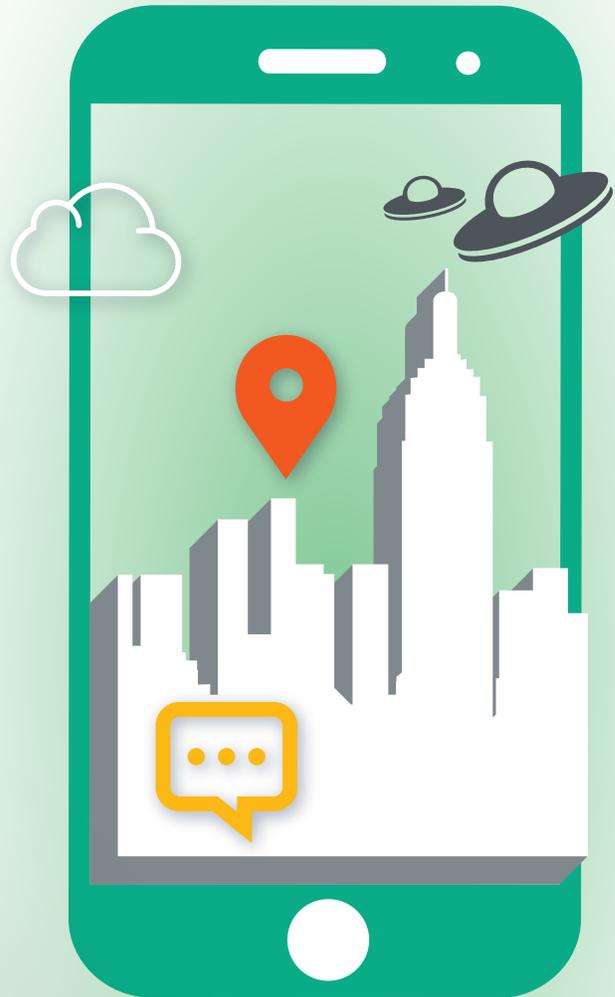
 Morelia

In the Logic Automatism Laboratory course, offered in the fourth semester of the B.Sc. in Mechatronics Engineering, students use an app called ARLAB (Augmented Reality Laboratory), which can be downloaded from Google Play website, to conduct experiments. This augmented reality application makes it possible to incorporate 3D models of mechanical components, such as conveyor belts, product dispensers, tanks with fluids, etc., allowing the emulation of complete industrial automation systems by combining them with physical devices, such as PLC (Programmable Logic Controllers), electric actuators and pneumatic actuators.

The physical elements are typical learning units of the course complemented with the three-dimensional models of the app, in Augmented Reality format, in order to obtain a complete view of an industrial system, thus clarifying the knowledge that generates interest in conducting experiments and meaningful learning. Therefore, students do not have to imagine part of the machine, an issue solved using Augmented Reality, which is an efficient, affordable solution.

In the course, students implement a bottle-filling production line, constructed with the interconnection of a pneumatic cylinder, an electric motor and a PLC with its respective programming, as well as the mechanical structure made up of a conveyer belt, liquid dispenser and a set of bottles. The latter are provided in virtual format with 3D models introduced with the application called ARLAB (in-house development, financed with the NOVUS 2013 fund), while the former are tangible elements that form a part real, part virtual Augmented Reality scenario.

This experiment was developed in 2014 and has impacted approximately 54 students, who expressed that this type of educational technology facilitates and motivates learning. During the experiment, we observed that participants were fully focused and looked relaxed and happy doing this type of dynamic, fun practical activities. These results validate that Augmented Reality is an excellent option for enhancing students' practical skills and knowledge.



**RA**



To determine the preliminary project results, we administered an opinion survey to a couple of groups who were shown the application. Of the 38 students who participated, 84% commented that this tool is an excellent academic support; 80% believe that it can help them to improve their academic performance in the course; 82% said that they would have liked to study cell structure and functions with this application; and 82% consider that it has an appealing interface.

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Tecnológico de Monterrey developed an educational laboratory platform with Virtual Reality machines, in response to low-cost laboratory equipment needs and as a high-tech educational resource that enables students to validate their knowledge and acquire new competencies in leadership, teamwork, etc.

The courses Industrial Networks, Industrial Network Projects and Integrated Manufacturing Systems used the automation laboratory with Virtual Reality machines that enable students to interact with virtual models that are connected to real industrial equipment. These machines simulate diverse industrial processes, such as an industrial warehouse, a machining cell, a sorting machine and an elevator.

This laboratory allows students to view and observe the behavior of diverse actuators and sensors and then program an automation sequence, requested by the teacher. Virtual Reality machines make it possible to enjoy more interactive laboratories and offer a wide variety of automation practices for students.

The implementation of this low-cost laboratory is an attractive option for equipping automation and process control laboratories. Virtual reality machines have had an enormous impact on engineering students, given the diversity of technologies implied in their development, and the diversity of practical activities that can be developed. Students experience an active, visual learning and teamwork, where, apart from the knowledge inherent to the course, they also acquire leadership, critical-thinking, problem-solving and collaborative-work competencies.

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To facilitate student learning in the course Fundamentals of Life Science, an app was designed and developed using Virtual Reality, which contains animal and plant cells and makes it possible to view their components and structure. With the help of this application, the learning process changed from being abstract to become an experiential learning experience. The novelty of this project consisted of transporting students to a microscopic level with a virtual journey inside the cell and its components.

The impact on learning centered on the identification of the parts of a cell and the functions of each organelle, through close-ups with 3D images to gain a greater understanding of cell biology. The application used is called “VC Trip Cardboard”, a free app available on iOS, Google Play and Oculus Store. The experience made students feel immersed in another reality through the use of special equipment, such as: visors, the app on their cell phone and headsets.

The Immersive Technology project of Tecnológico de Monterrey in León is based on the pillars of the Educational Model Tec 21 and on the evolutionary process of technology in education. It focuses on providing interactive and experiential learning experiences that captivate and motivate students, while engaging them in their learning process through challenges in Virtual Reality, with the teachers as the main promoters of this technology.

The aim is to obtain valuable information from users through training workshops for students and faculty and implementations in the classroom, in the initial stages of the process of adopting immersive technologies in education, in order to facilitate their appropriate implementation and exploit all their potential based on the perceptions and needs of the campus's educational community. The project was based on Google Cardboard, which makes it possible to experience Virtual Reality in a simple, inexpensive manner.

Using Google Cardboard, in the Trigonometry course, students had the opportunity to visit different places, such as Paris and Tokyo. They worked in pairs, with one student in charge of reading the instructions and narrating to his/her partner what he/she should be seeing through Google Cardboard. In the process, the partner is asked to look at the top of a building, for example the Eiffel Tower. In this position, the student who is reading the instructions measures the degree of inclination of the cardboard using the Winkelmesser LITE application. Students then used trigonometry to find how far they were from the place, knowing the height of the building.

Despite the mishaps that might occur in a session that uses this technology, based on my experience I can confirm that is well received by students and teachers alike, with 88% of students and 90% of teachers wanting to have another virtual reality experience in their classes. Moreover, 82% of students and 85% of teachers perceived value in Virtual Reality as a support in the teaching-learning process, which helps us to detect an alignment between the way students and teachers feel about immersive technologies and sets the standard for a greater promotion.

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Practical activities were developed in the course Industrial Network Projects and the elective course Advanced Industrial Automation that enable students to understand and develop virtual environments for the area of manufacturing. In addition, students integrate virtual environments with physical control elements giving rise to the so-called cyber-physical systems.

At the start of the project, training is provided on the use of the computer platforms and existing methodologies to generate cyber-physical systems and virtual environments. These stages consist of: Digitalizing in three dimensions a manufacturing or assembly process (NX, Catia, etc.); determining the functioning logic of the process and developing a pilot control program using the guide mode start and stop (GEMMA); generating the virtual environment in which each component of the computerized drawing is given a specific function according to the physical process, such as: sensors, actuators, control or static elements (support). The computer platforms used in these assignments are Solidworks, Delmia Automation, Tecnomatix or NX.

Afterwards, the virtual environment is integrated with a simulated control element, such as the PLC SIEMENS (PLCSIM) simulator. At this stage, students refine the pilot control program, by observing and comparing the behavior of the virtual process with the real process; the control program is uploaded, refined in the virtual environment, to the PLC. The latter is the controller of the real process. The process must be executed without errors, since the program refining was executed in the virtual environment.

Finally, a communication system is generated that allows the virtual environment to exchange data with a PLC control element. The OPC (OLE for Process Control) communication mode is used and communication between the PLC and the virtual environment is verified, producing the cyber-physical system. In this way, the virtual environment turns into a monitoring system that replicates and modifies the behavior of the real process.

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 Academic and Educational Innovation Vice-rectory

During the summer of 2017, the Department of Basic Sciences of the School of Medicine decided to incorporate the Virtual Reality application 3D Organon VR Anatomy into its learning support tools for the course Musculoskeletal and Digestive Systems. Virtual Reality technology has allowed us to enrich our students' learning, since it creates a simulated real environment where students find out about the different systems of the human body: Muscular,

Digestive, Nervous, Skeletal, among others. In addition, students have the opportunity to view close up the real dimensions of organs and muscles that might have been impossible or difficult to achieve with traditional teaching methods. This has enabled us to evolve and leave common learning practices behind.

Classes were structured so that the topics seen with the teacher will be complemented with practical sessions in the Virtual Reality laboratory, which were designed by the academic responsible for the course. Each practical session completed by students was recorded and delivered as part of their assessment evidence. Teacher-student interactive reinforcement sessions were also carried out.

The results of a survey administered at the end of the course supported our idea that this technology has huge potential and a future in the areas of Basic Medical Sciences. The most important findings were:

86% of students said they very much enjoyed the practical sessions and would attend even if they did not have any grade value. 94% confirmed that it helped them a lot to understand the three-dimensional aspects of human anatomy, which has always been a need for students who study this course. Approximately 50% mentioned that it helped them to learn physiology, even though the application does not address these concepts. Another

interesting piece of data is that 60% of students would agree to attend a practical session alone, thus confirming the need for the practical sessions to be completed in teams.

Given the satisfactory results obtained, the Department of Basic Sciences of the School of Medicine decided to continue with the incorporation of this type of teaching support technologies, and also to include it in the courses Basic Morphophysiology and Biocontrol Systems.



# Relevant cases at other institutions

## AR AUGMENTED REALITY

### Languages

Institution: **University of Victoria**  
Country: **Canada**

Description: By means of a mobile application, the university campus becomes a French-speaking environment in which students can interact with diverse quizzes and added linguistic information. The pedagogical design that forms the basis of this proposal is based on gamification (Perry, 2015).

### Biology

Institution: **Universidad Popular del César**  
Country: **Colombia**

Description: A biology book was generated containing triggers that, through a mobile application, make it possible to view different types of living beings in 3D, as well as a series of interactive exams to check evolution in learning this content (Retrepo, Cuello and Contreras, 2016).

### Teacher training

Institution: **Universidad de Castilla la Mancha**  
Country: **Spain**

A group of trainee teachers participated in a workshop for designing educational materials with AR, taking advantage of open-source portals, such as Aumentaty Author or ARToolkit. The experience included piloting these materials in the classroom and the evaluation of a questionnaire answered by students to document their learning experience. The main challenge was overcoming the mere attractive and anecdotal use of this technology to achieve a greater impact on enhancing skills (Cózar et al., 2015).

### Engineering

Institution: **Universidad de la Laguna**  
Country: **Spain**

With the aim of developing spatial thinking in Fine Arts students, an application was used to project three-dimensional models that students could manipulate with their hands in a very similar way as would occur with objects of these dimensions. In a study conducted after the implementation of AR, students reported an improvement in their attention in the course and the feeling of the usefulness of the didactic resource (Gutiérrez et al., 2010).

### Ethics

Institution: **Universidad de Almería**  
Country: **Spain**

The AR videogame VEAR (School Violence and Academic Performance) generates a sociogram of interactions with other participants, rewarding relationships based on collaboration and penalizing those that lead to isolation. This all takes place within the real context of the classroom, thus allowing students to become aware of the ethical implication of their interactions with their classmates (Pérez-Fuentes et al., 2011).

### Environmental engineering

Institution: **MIT**  
Country: **USA**

Description: Students roleplay as environmental engineers who go around the Campus trying to investigate the source of a carcinogenic toxin and generate a safety plan. The application works with geolocation and offers clues and scientific information in different points of the campus, such as the chemical composition of some materials, EPA regulations, the recommended soil remediation strategies and the health risks associated with the toxin.

### History

Institution: **UNED (in collaboration with Telefónica)**  
Country: **Spain**

Description: Using an application, students (in fact, any citizen) can walk around the old center of Madrid (Madrid de los Austrias) accessing articles and multimedia geolocated information on the history of the city in the 17th century, including customs, clothing and festivals of that era in those very places. The application can suggest collecting evidence, solving riddles and locating concrete points on a map of that era.

### Business

Institution: **Universidad Autónoma de Nuevo León**  
Country: **Mexico**

Description: A study was conducted among the business school teachers to determine how much they used emerging technologies like AR. The results of the questionnaire report that 14.3% use an AR application in their classes (Madrigal et al., 2017). One of the advantages of doing so is the growing use of AR in startup companies, focusing particularly on marketing.

### Libraries

Institution: **The SCARLET Project**  
(universities, libraries and museums)  
Country: **UK**

Description: The objective of this project is to make it easier to consult ancient documents, such as manuscripts, adding AR layers to the consultation. The project was financed by Joint Information Systems Committee and involved the participation of a network of libraries, museums and universities. One of the main outcomes is an increase in consulting these collections (Natalia, 2016).

### Medicine

Institution: **Universidad EAFIT**

Country: **Colombia**

Description: Use of collaborative surgery simulators to train medical students in teamwork skills in the operating room, such as the concrete case of a gallbladder removal (cholecystectomy). Players manipulate virtual surgical instruments and monitor different data to find the best collaboration practices within a surgical process.

### Urban planning

Institution: **Universidad Politécnica de Cataluña (UPC)**

Country: **Spain**

Description: After an investigation by the UPC Faculty of Architecture, in collaboration with archeologists from Universidad de Girona, a series of virtual models were developed of the ancient Gironella Tower, a historical enclave from the city's Roman era. The results of a questionnaire administered to the students who participated in this activity highlight the high degree of satisfaction regarding learning spatial skills.

### Citizenship and social empathy

Institution: **Universidad de Barcelona**

Country: **Spain**

Description: In the Serious Game Design workshop, as part of the Common Games project entrusted by the Barcelona City Council, students designed a VR game that permits immersion in the life of a homeless man. The objective is to create awareness about this social drama, confronting the prejudices that exist toward the poorest and most socially excluded members of society, and experiencing poverty in a less conceptual and more situated manner.

### Multidisciplinary: architecture, engineering and construction

Institution: **George Mason University**

Country: **USA**

Description: The purpose of the program is to rethink the relationship between architecture, engineering and construction within a VR space designed on Quest3D, with problems for which students have to offer creative, non-routinized solutions in the disciplinary models in which they have previously been trained. One of the conceptual tools offered is the theory of the seven principles of Da Vinci, reinterpreted in light of the conditions and materials of actual construction.

### Mechatronics engineering

Institution: **University of Warwick**

Country: **UK**

Description: The software Autodesk Inventor projects in 3D a simulation of an automobile engine with several options for its installation and operation. Students can test the effects and measurements of each of the mechanisms and, therefore, make better design and modeling decisions for this type of engines.

### Nursing

Institution: **University of Wolverhampton**

Country: **UK**

Description: Trainees are offered an immersive experience in hospital activities. Using headsets, they access a scenario with dementia patients, family members and other subjects. The objective of this "serious game" is to manage nurses' professional interaction and do so in an environment that is as realistic as possible, before taking the leap into practicing in a real hospital.

### Dentistry

Institution: **University School of Dental Medicine**

Country: **USA**

Description: Using a haptic simulator, which not only recreates tooth dimensions in 3D, but also vibrates or lights up when the healthy part of the tooth is removed, students can extract cavities from damaged teeth, calibrating the precision and efficiency of their manipulations.

### Chemistry

Institution: **University of Malakand**

Country: **Pakistan**

Description: Professors at this university developed a program that reproduces in 3D the conditions and instruments of a chemistry laboratory. They trained teachers of this specialization from diverse high schools in the country, so their students could explore different chemical reactions and digitally manipulate basic laboratory tools on their laptops.

### Languages

Institution: **University of Surrey**

Country: **UK**

Description: In a virtual 3D environment with avatars (IVY 3D), students can immerse themselves in high-value communication situations (tourist information offices, hospitals, business meetings) and participate in recorded dialogues, learning to solve communication problems in bilingual communication contexts.

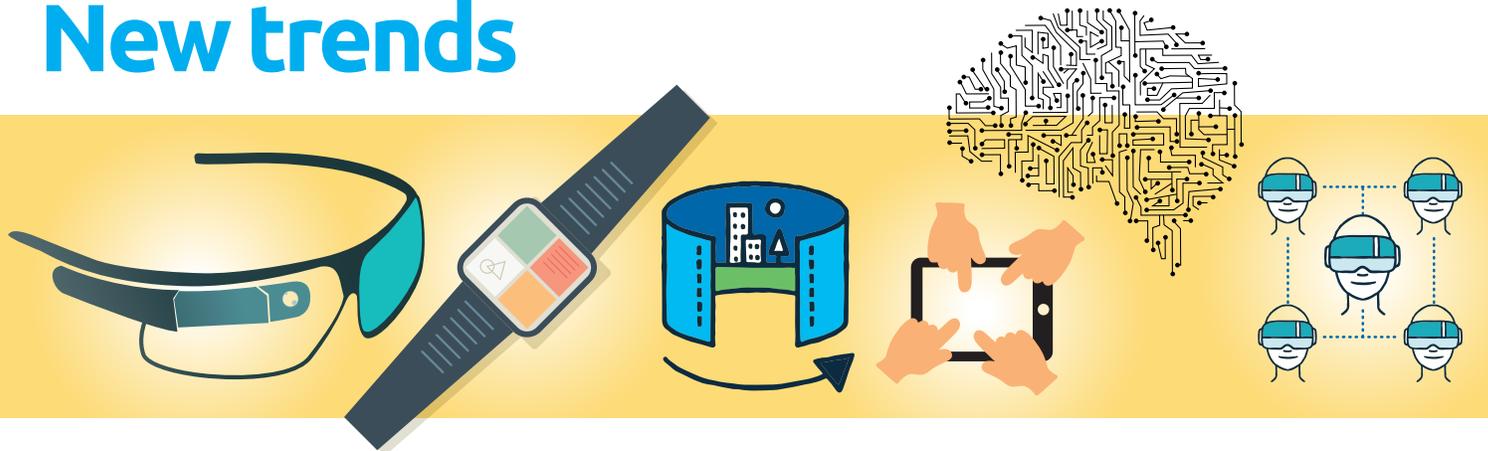
### Computer science

Institution: **Universidad Carlos III**

Country: **Spain**

Description: This learning project consists of modeling objects in 3D, conversational metabots and operating system management within Second Life or Opensimulator, as a strategy for developing knowledge related to language processing and artificial intelligence. Students perform these exercises within an immersive environment in which teachers and other students can interact.

# New trends



## Collective interactive environments

The development of VR videogames and AR apps has evolved from the first individual uses toward a multi-user experience in which several players or participants interact in these digitalized scenarios. In terms of learning, this makes it possible to create activities centered on collaboration. Surgical simulation exercises performed simultaneously by teams of medical students or gymkhanas in tourist spaces or university campuses are just the start of a world yet to be explored.

## Integration of artificial intelligence and the human brain

The nonstop evolution toward a human reality increasingly assisted by digital technology brings us closer to one of humanity's dreams or nightmares: the era of homo cyborg. Specifically, the company Neuralink, recently relaunched by Elon Musk, is investigating the possibilities of connecting the human brain to digital applications that would add information or depleted operating functions. The objective of the project is to drive cognitive human capacities through brain implants. Although, the current early experimentation stage focuses on treating neurological diseases such as epilepsy or Alzheimer, it is actually difficult to foresee what its evolution and applications could be.

## Collaborative design of digital applications by students

The systems for creating AR and enriching virtual models are increasingly simple and do not currently demand specialized knowledge of programming. This allows educational systems to involve students in the co-design of these resources, making them not only consumers, but also educational "prosumers". An example consists of the AR tourist applications that allow users to add information to the app.

## Development of wearables

The AR and VR market is evolving towards devices that are increasingly easier to carry. The next step, already under development, is to integrate these devices into objects that we can wear, known as Wearables, such as smart glasses, contact lenses, bracelets or watches. These devices could be interconnected wirelessly to other digital devices, integrating our human experiences into an environment where reality and virtuality are constantly interchanging data and reactions. So far, one of the obstacles of these devices has been their high cost and lack of ergonomics, but multimillion investments by major technology companies in the development of new prototypes make it hard to imagine that these challenges cannot be overcome in the short term.

## Blend of Virtual Reality and Augmented Reality

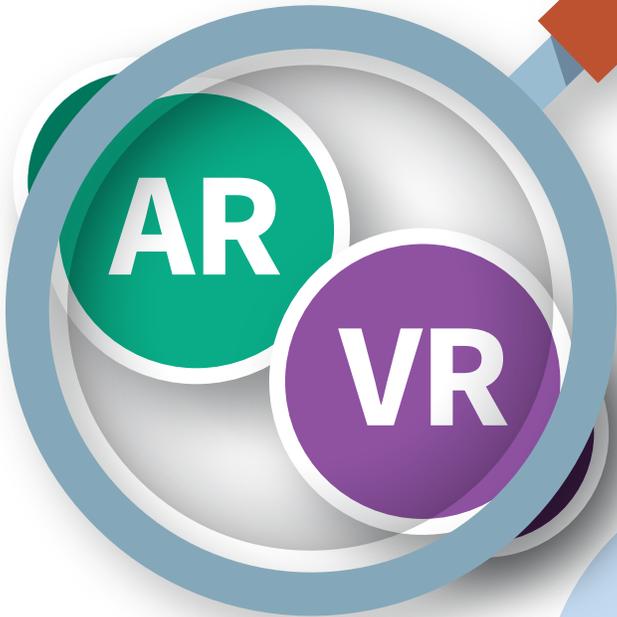
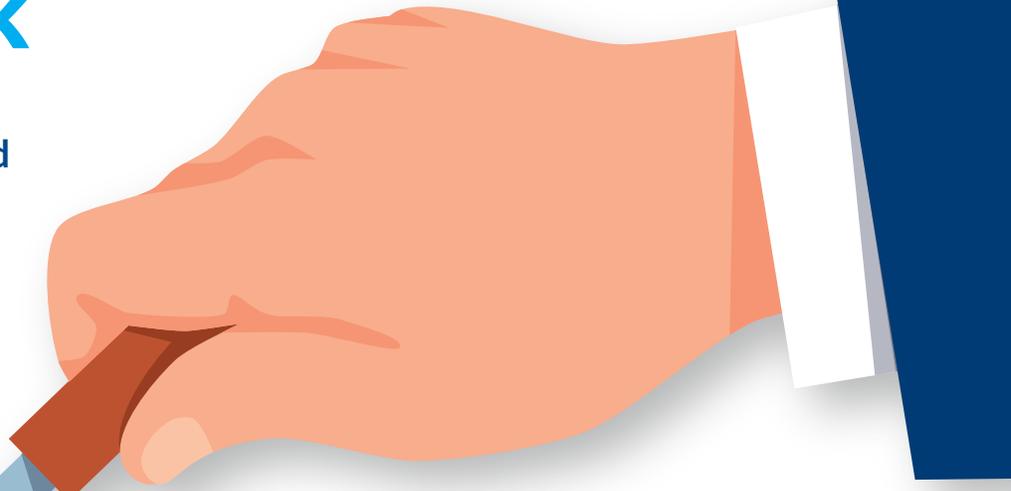
Some companies have announced their projects that blend both tools. Intel, for example, presented the device with which they are foraying into the world of immersive entertainment. Project Alloy is an HMD that merges Virtual Reality and Augmented Reality and is an independent hardware that does not need any sort of external CPU to function, in other words, it functions autonomously. The 3D cameras in the lenses capture the user's hands, thus offering the possibility of interacting with the virtual scenario or introducing elements of the real world into the digital environment.

## Geolocation

The use of AR and VR in geolocation simplifies and automates common tasks, since Augmented Reality makes it possible to overlay digital information in the real environment and implies a huge improvement to the effectiveness of visual interfaces for training, maintenance and service needs in smart environments (such as smart cities). Meanwhile, Virtual Reality makes it possible to use digital environments in training for complex or dangerous activities and in supervising control center processes and operations (such as infrastructure management).

# A critical look

Several issues indicate that not everything about Augmented Reality and Virtual Reality is positive in relation to the use of technology, as can be seen below:



The cost of producing electronic devices with AR and VR can be prohibitive; consequently, generating an immersion experience is difficult.

The technology for creating such experiences is new and experimental, meaning that in the field of education there are still several aspects related to learning that need to be investigated and analyzed.

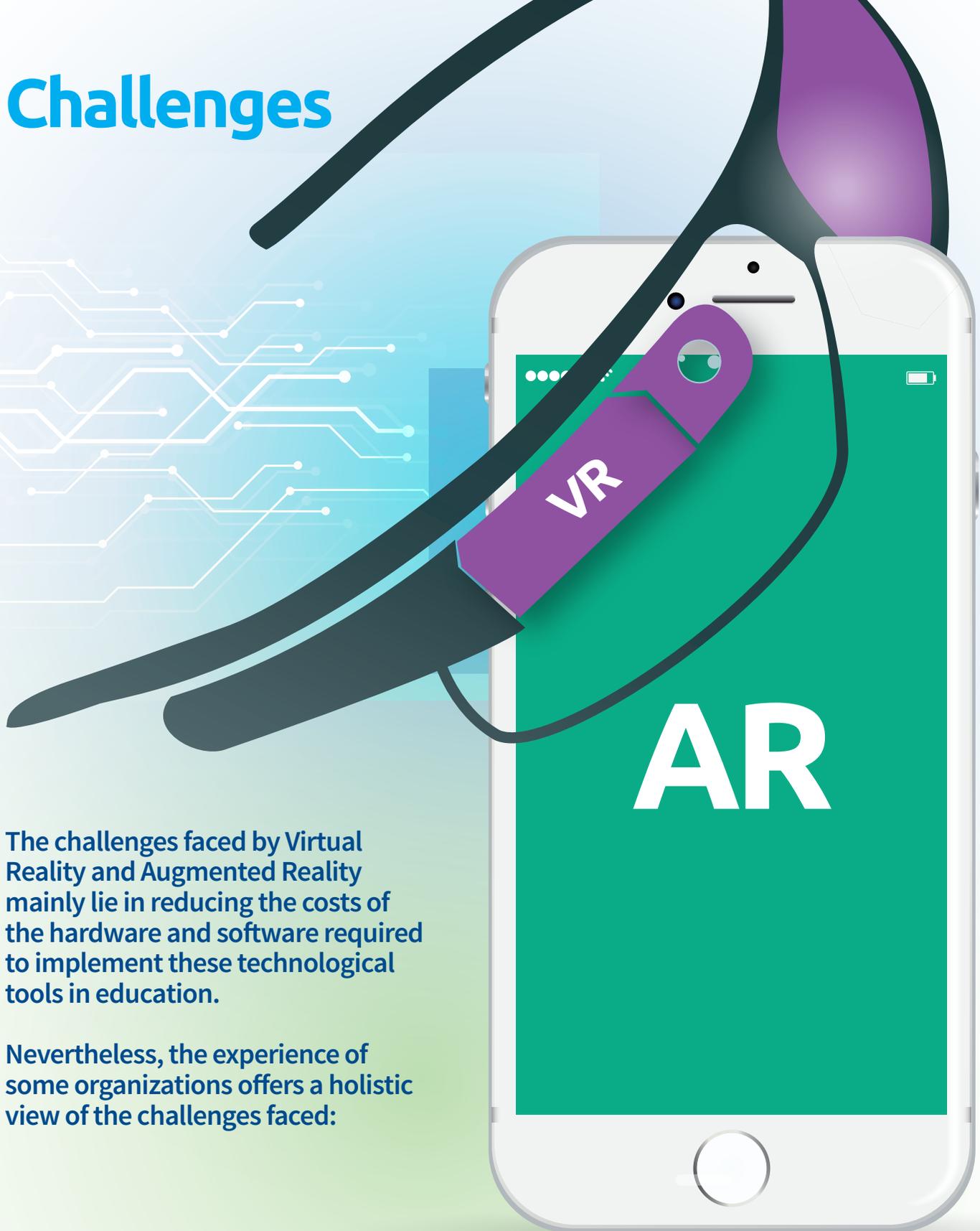
Collecting and containing information on everything needed to implement Augmented Reality and Virtual Reality requires a great deal of time and effort.

Very often, human beings no longer communicate face-to-face and virtual relationships are becoming increasingly preponderant, which can generate uncertainty, weak affective ties, banalization and escapism. This situation could be significantly accentuated with the use of AR and VR.

The consequences of training in a VR environment are not the same as training and working in the real world. This means that even if someone works well with simulated tasks in a VR environment, that same person might not do so well in the real world.

The data processing speed required is extremely high in comparison with today's most popular electronic devices. This is due to the fact that all the images captured on video need to be analyzed in order to recognize them and perform the respective actions that subsequently emerge.

# Challenges



The challenges faced by Virtual Reality and Augmented Reality mainly lie in reducing the costs of the hardware and software required to implement these technological tools in education.

Nevertheless, the experience of some organizations offers a holistic view of the challenges faced:

1

Generation of excessive expectations. Sometimes people speculate that every single action that can be performed in reality can also be executed in virtual environments. In this respect, it is important to carry out all the necessary procedures to achieve coherence between the virtual world and the real world.

2

The development of skills in specific fields and according to each individual's needs.

3

Current limitations in the development of more and better apps and learning outcomes with AR and VR.

4

Reduction of the educational digital gap between institutions, regions and social sectors with access to AR and VR technology and those that do not yet have the same technological opportunities or capacities.

5

The learning curve for teachers and students (Cadavieco and Pascual, 2017).

6

They are developed around diverse areas of knowledge, seeking to become transdisciplinary tools.

7

Technology is fast faced, so the changes in the electronic devices that give life to this type of tools are updated at high speed.

# Recommended actions for teachers

In education, Augmented Reality and Virtual Reality have been adopted as the leading trends in educational technology. There are several applications in the area that are based on these tools, which are used inside and outside the classroom. For example, projects are used in the classroom to complement activities or the protagonists of the same, where students and teachers are normally the ones who generate the information shared.



The Observatory of Educational Innovation proposes the following recommendations for teachers regarding the implementation of AR and VR in their classrooms:

1

Make sure that the technology of the hardware and software are optimal and match the demands of your subject's content. The devices must have the appropriate sensors and preferably high-resolution screens.

2

The electronic devices you recommend for a specific class must be comfortable for users, i.e. not make students tired or physically exhausted.

3

Teachers must oversee the connectivity and compatibility aspects of the devices used in the classroom.

4

Check that students can easily interact with complex information.

5

Activities must be designed in such a way that students can interact and form part of the narrative that leads them.

6

An excellent strategy for stimulating learning is to generate debates based on what has been observed in the real world and in the virtual world.

7

The optimal use of tools makes it possible to complement the topics studied in the classroom and, therefore, the use of services such as geolocation (GPS or compass) or triggers (QR codes) is recommended.

8

Collaborative activities help to construct knowledge based on teamwork.

9

Foment social relationships among students.

10

Motivate learning by doing.

# Recommended actions for academic leaders

To implement Augmented Reality and Virtual Reality in educational institutions, academic leaders should address the following aspects:



# Credits and Acknowledgements

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