Juan Ramón Moreno-Vera /
José Monteagudo-Fernández /
Cosme Jesús Gómez-Carrasco (eds.)

Teaching history to face the world today

Socially-conscious approaches, activity proposals and historical thinking competencies

PETER LANG

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In terms of new approaches, this book suggests activities regarding invisible topics such as social and economic impacts in history, inequalities, church and science, gender equality, power and violence, prosecuted by justice, peasantry and the urban world, family and daily life, terror or travelers and their cross-currents.

Regarding the activities, the incidence of new technologies in social relations and the effects of globalization is very remarkable for our students. The authors highlight the need for changes in teaching and learning history.

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Abstract: This book develops the challenges that history teaching must face as a curricular subject at the beginning of the 21st century. These challenges are related, both to new epistemological approaches in history education, and also to the development of new activities, active-learning methodologies, and historical thinking competencies. In fact, one of the most important targets of this book is to develop concrete actions and activities that teachers could easily adapt to their classrooms realities.

In terms of new approaches, this book suggests activities regarding invisible topics as social and economic impacts in history, inequalities, church and science, gender equality, power and violence, prosecuted by justice, peasantry and the urban world, family and daily life, terror or travelers and their cross-currents.

Regarding to the activities, the incidence of new technologies in social relations and the effects of globalization is very remarkable for our students. In this sense, active-learning methodologies are oriented towards know-how, without forgetting basic historical knowledge. Activities work with different information sources, historical evidences and problem-based exercises to make the students learn in an increasingly heterogeneous society. That way, the authors highlight the need of changes in teaching and learning history.

At this point, historical thinking competencies emerge as an educational path to follow, allowing new ways of learning: investigation of socially relevant problems, cooperation among students, critical thinking and the use of media, inquiries and scientific research, skills development and developing democratic values to improve the world today.

Keywords: Historical thinking competencies, history education, socially-conscious learning, ITC activities, globalization.

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Ramón Cózar Gutiérrez/Alejandro López-García

Chapter 3. Emerging technologies: Virtual reality, augmented reality, and robotics[1]

Abstract: Emerging technologies are made up of state-of-the-art software and hardware whose developments converge in innovative procedures and practices capable of proposing methodological alternatives and contributing to educational efficiency. In recent years, abundant research and numerous national and international reports have tackled the most relevant technological trends and practices in educational contexts. This chapter explores virtual reality (VR), augmented reality (AR), and educational robotics (ER) as the main emerging technologies. The text defines and characterizes their scope, highlighting their possibilities and limitations for practical implementation. Remarkable benefits are observed in terms of improvements in interest, motivation, and academic results, among others. The importance of increasing training to bridge the gaps in teachers' knowledge, instrumental skills, and pedagogical practices is also emphasized. The chapter concludes by underscoring that educational administrations must make a firm commitment to these technologies, as a turning point to transform the quality of learning in the 21st century.

Keywords: Educational technology, virtual environments, immersive technologies, emerging software, educational technology

Introduction

Digital society is transforming. The role inspired by social networks, cloud learning, the semantic web, learning analytics, 3D printing, big data, digital transformation, virtual environments, and even new artificial intelligence systems, are proliferating at breakneck speed, becoming fundamental drivers and benchmarks of knowledge, in continuous technological development. The transmedia strategy or media convergence must acquire a fundamental role in educational progress, making use of the combination of technological

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advances and their languages. This task can be concretized in the irruption and consolidation of mobile technologies from an approach or prism that transforms the communicative environment, improves the creation of digital content, rewards the self-realization of students, values virtual interaction, and has an impact on society.

There is no denying that how human beings experience educational reality is changing thanks to technology, which has become a reliable driver of learning. The emerging technologies of the 21st century are moving through this kind of *digital convergence*, materialized in the form of video games, technological applications, gamified platforms, and other interactive experiences that give the user a leading role that he or she has never had before. Added to this is the emergence of robots as devices capable of undertaking operations or jobs that develop certain human skills and on which educational techniques and practices are implemented.

During the 21st century, the Horizon Report has become the main reference for many professionals interested in learning about the most relevant trends in educational technology. These observational guides are based on numerous predictions made by expert educational technologists about the impact of technology on teaching and learning. Some of these reports have focused on important developments in educational technology and practice across all stages of education, highlighting exciting developments applicable to the field. Kenneth and Wen (2022) present an updated picture of trends in K-12 educational technology in the past and near future, comparing predictions of technologies across seven Horizon reports in a way that identifies broader trends from individual predictions, all while assessing the accuracy of the prediction through bibliometric analysis. This paper identifies six influential technologies in educational practice: mobile, gaming, analytics technologies, maker technologies, artificial intelligence, and simulation technology, given that one should not rely solely on a single year's predictions, but on long-term trends that emerge from the most recent individual reports, which are influenced by the availability of new technologies that emerge or become prominent on a yearly basis. Within simulation technologies, this paper highlights the potential of augmented reality and virtual reality as technologies that have set and continue to set trends, highlighting the years between 2016 and 2019, as a result of Google's Glass project, advances in iOS and Android operating systems, the availability of affordable virtual and augmented reality via mobile phones, the development of platforms such as Oculus or Play Station, or the latest Head-Mounted Displays, which are setting trends in the sector. And on the other hand, within the framework of the maker movement, apart from spaces where technology is not needed, the contribution of emerging technologies such as 3D printing or robotics is analyzed. In line with the evolution of the robotics industry, educational robotics is proposed as a trend in 2016 and 2017 with an impact on education in the medium and long term.

This chapter addresses this issue from a triple perspective -VR, AR, and ER-, defining and specifying the scope of study of each of these concepts that delimit the technological field of virtual environments and programming, as interesting spaces whose possibilities of implementation are paving the way to renewed trends and significant changes in terms of research and innovation.

Background of mixed reality environments

The technological emergence based on AR and VR is an irrefutable reality in the educational field. However, its irruption must be considered from its historical perspective, since the technologies that emanate from virtual environments have undergone a historical process of evolution, development, and maturation that allows us to understand that both its beginnings and its transition and consolidation in the sector have not been simple.

The first precedents that delimited the boundaries of virtuality appeared in 1931, the year in which Link, a pilot, and mechanical engineer, patented the first flight simulator. One of its main objectives was to provide a device for the training of aviators and students, so that they would be subjected to all the natural sensations of flight, as if they were in a real airplane, thus being able to acquire the experience to perform turns and movements in a device of this caliber (Link, 1931).

Based on the above, it is necessary to advance past the middle of the 20th century to highlight the legacy of Morton Heilig, philosopher, inventor, and filmmaker, considered the father of VR and AR, whose historical inventions marked the way forward in subsequent developments in mixed reality. In 1960, this author invented the Telesphere Mark, which he described as a stereoscopic television apparatus for individual use (Heilig, 1960). This instrument was considered the first *Head-Mounted Display* (HMD), a screen or display placed on the head, consisting of a hollow housing, a pair of lenses, two headphones, and two air transmission nozzles, whose functionality was to provide the user with a 3D view, complemented by air sensations and real stereo sound effects. Heilig also implemented in 1962 a prototype of an idea he had five years earlier, on a device that would stimulate the senses. In this way, he built a sensory immersion machine called *Sensorama*. Basically, it was a simulator that included various moving images with smell, real stereo sound, vibrations in the seat, and wind in the hair, to create an optical illusion, under an exciting virtual reality experience (Heilig, 1962).

The developments and advances of the 1960s had a notable international influence, which converged in several advances whose zenith was not yet in sight. In this context, it is necessary to highlight the influence of Sutherland (1968), who presented the first unique AR mechanism. It was a very large helmet or HMD, hanging from the ceiling, whose fundamental idea was to present a virtual image in a perspective that changed as the user moved, reproducing polygons. It was the first mixed reality invention, as it allowed virtual images to be superimposed within the user's natural field of vision and, although it initially had many limitations, especially in terms of graphics, it marked the starting point for the main features on which AR and VR would later be based, namely: position sensors, 3D graphics, stereoscopy, navigation on the axis of an object, viewing in various positions, etc. These advances had a significant influence on the development of Head-Up Displays (HUD), which – from the military sector – would later evolve in the aviation and automotive industry. Undoubtedly, this technology marked the beginning of very interesting opportunities to project relevant information into a person's field of vision, enhancing their experiences with additional virtualized information.

Shortly thereafter, Heilig (1969) again patented a version of *Sensorama* for a wider audience. It consisted of a theater where the spectators could sit in armchairs and had access to the visualization of large hemispherical screens, with three-dimensional moving images and peripheral images, complemented with several loudspeakers placed inside the theater and with the possibility of feeling aromas, wind, variations in temperature and inclination of the support plane of the chairs, involving the spectators in a virtual movie that made them feel a real experience.

Figure 1 shows Heilig's patented inventions, as well as Link's flight simulator and the HMD described by Sutherland.

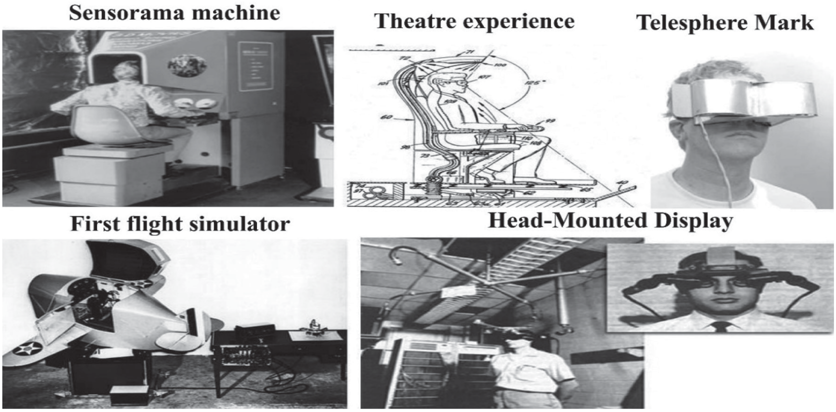

Figure 1: *Major historical mixed reality inventions*

Note. Adapted from Sensorama Simulator, *Experience Theater,* & *Stereoscopic-Television Apparatus for Individual Use*, by M. L. Heilig, 1962, 1969, 1960; *Combination Training Device for Student Aviators and Entertainment Apparatus*, by E. A. Link, 1931, & *Head mounted three-dimensional display*, by I. Sutherland, 1968. Creative Commons license.

The next breakthrough that laid the foundation for this symbiosis between the real and the virtual was *Videoplace*, created by Krueger in 1985. This was a room that allowed users to interact with virtual images for the first time, without touching them. The human-machine interface facilitated physical participation with graphic images, which were played through a video that the user made live, all in real-time (Krueger et al., 1985). This creation was well accepted during this era and led to decades of research and reworking of the system, highlighting its evolution into game controllers or even the development of more recent holographic techniques. Figure 2 shows an example of interaction through Videoplace.

Figure 2: *Krueger's Videoplace*

Note. Taken from Videoplace, de M. Krueger, 1985. Source: http://www.inventinginteractive.com/2010/03/22/myron-krueger/. Creative Commons license.

Other relevant and influential historical examples -which contributed to their mixed reality nuance- were films such as *The Terminator* (1984) and *RoboCop* (1987). In these films, reality and virtuality appear fused inside the bodies of their protagonists, as machines that could see the real world from their virtuality and interact with the environment with additional information being superimposed on their visual system, showing itself to the viewer.

This led to 1990, which marked a decade in which concepts such as AR (Caudell & Mitzell, 1992) or mixed reality were coined, formally embodying the main descriptive terms of immersive environments, as evidenced in the description of the virtuality continuum (Milgram & Kishino, 1994), a taxonomy that gathers all the existing visualization modalities, being able to juxtapose each other, so that real and virtual elements coexist in the same mixed reality space, with AR being located closer to the completely real environment than to the completely virtualized environment.

Throughout the 1990s, industrial and military applications were also developed, but the technical requirements for visualization of AR and VR were too costly and beyond the possibilities of the average user. However, at the end of the 20th century, a video-based AR conferencing system using markers and calibrated HMDs was created (Kato & Billinghurst, 1999). With this work, Kato would establish the basis of *ARToolKit*, a powerful library that allows programmers to design AR applications at lower cost and for all domains, thus giving rise to greater accessibility that would encourage the creation of other similar libraries (Mullen, 2011). Mixed environments were already a reality in the consolidation of virtuality, which reached its apex in the last years of this century.

Virtual reality in education

VR consists of the representation of scenographies and images provided by a computer, in a way that simulates a real, three-dimensionally enhanced experience. Lissa and Bhuvaneswari (2022) define the term as the use of computer technology to design environments that allow the user to interact with the 3D universe, simulating senses such as sight, touch, hearing, or smell, so that an artificial environment is created to experience the world in three dimensions. In other words, thanks to VR it is possible to create a fictitious environment that functions as a scenario that has a realistic appearance with reconstructed or enlarged information, which facilitates users to move to any place or situation, creating a totally immersive sensory illusion.

The Educause report (Brown et al., 2020) states that the use of VR is in continuous growth due to the potential offered by its immersive characteristics, its accessibility, and the progressive reduction in costs which, together with new technical developments in mobile devices, enhanced wireless networks, and connectivity, increase the number of immersive experiences. The sensory experience that certain computing devices can provide is an unprecedented advance in educational technology. Today, a cell phone, a pair of glasses, a helmet, or any other visor are hardware devices that enrich access to information that, if worked well by educational institutions, can become knowledge, adding the value of doing so from a ubiquitous prism that simulates reality and improves it, for the benefit of students who demand new ways of learning and access to knowledge. Therefore, VR is a powerful tool to implement multisensory experiences in which the user makes the decisions and controls his own reality (Martín-Gutiérrez, 2017).

The three-dimensional contents that enter the scene in these experiences can be dynamic or static, that is, with or without animations. In addition, they may or may not be interactive, so that the user has more or less relevance in the virtual environment, and the experience has more or less realism. Examples range from simple 3D objects to video games, applications, or computer-designed virtual worlds. Virtual reality systems can be of three types: immersive, semi-immersive, and non-immersive, so that each has specific characteristics that users experience differently.

Immersive virtual reality systems represent the highest level of immersion. In these systems, the user observes the virtual world from within the environment itself, developing a sense of presence and prominence, so that the scene is constantly updated as the user moves (Di Natale et al., 2020; Villena-Taranilla et al., 2022). Semi-immersive VR systems, on the other hand, are characterized by a total lack of presence in the digital environment. Flores et al. (2014) point out in this sense the importance of strengthening sensory inputs to improve the user experience with more active interactivity. Finally, non-immersive VR systems provide an external experience; that is, an environment of interactivity in a virtual world that can only be viewed through the screen of an electronic device, operated with a keyboard, mouse, or touch screen (Freina & Ott, 2015).

Among the features to take into account in these devices are the screen resolution, the refresh rate -expressed in Hertz-, the orientation sensors -gyroscope, accelerometer, and magnetometer-, the user's position tracking and the tracking latency that readjusts the image concerning its actual movement, the eye sensor, and the stereoscopic vision that enables the user for three-dimensional visualization. The latest HMD visualization devices (*HTC Vive*, *Oculus Rift*, *Samsung Odyssey*, or *Valve Index*, among others) favor a powerful degree of immersion in which users participate as the protagonists of a virtual setting that emulates presentiality and allows them to live experiences and visceral sensations as if they were physically in an environment that is not real. Even low-cost HMDs such as *Samsung Gear VR* or *Google Cardboard* allow access to experiences from the mobile device itself, facilitating the immersion.

In this field, immersive VR has been founded upon three elementary principles described by several authors (Freina & Ott, 2015; Gavish et al., 2015): immersion, interaction, and user involvement with the environment, so that they offer a very high potential providing more motivating and engaging learning. In fact, the approach of virtualized exercises allows students to retain more information and apply what they have learned in a more efficient way (Krokos et al., 2019).

These environments also allow students to inquire about new spatiotemporal realities and overcome certain difficulties of presentiality, either due to time constraints, physical inaccessibility, or the possibility of facing imminent dangers in real situations, by living these experiences and situations in virtual and immersive environments (Makransky & Lilleholt, 2018). In fact, the implementation of VR brings about new learning situations by giving the user an active protagonism under a real sense of immersion in scenarios that would be unattainable through the textbook or a technology that was not immersive or lacked the active protagonism provided by these experiences of three-dimensional interactivity.

The possibilities of VR in education are enormous. From visualization platforms to content creation or publishing tools, VR provides scenarios in simulated environments that can support dynamic learning experiences. Some examples are VR applications for smart devices (*Google Cardboard*), platforms for PCs or game consoles (*Oculus Rift*, *Valve's Steam*, *Play Station VR*, etc.), VR content focused on web browsers (*Sechelt* or *Inspirit*, among others), or the interactivity provided by virtual worlds, such as collective spaces where you can act in real-time through an avatar. Some examples of immersive or semi-immersive virtual worlds are *Minecraft* for *Oculus*, *Gear VR*, *Samsar*, *OpenSimulator*, *Second Life, Imvu*, *InWorldZ*, among others. On the other hand, there are design software that favor the creation of VR content. These are tools oriented to the modeling of three-dimensional objects and require a subsequent import to specific VR creation applications or platforms. Some programs in this regard are *Tinkercad*, *Sketchup*, *Wings 3D*, *Equinox 3D*, *Daz studio*, *3D Crafter*, etc.

At another level of immersion are the free applications or software that make it easier to generate VR content, enabling conversion to three-dimensional stereoscopic formats or 360º immersive scenarios, so that they can be viewed with a greater (using a VR viewer) or lower (from the computer) degree of immersion. Some examples are *CoSpaces Edu*, *Sketchfab VR*, *Fulldive VR*, *Google Earth VR*, *Holobuilder*, *VR Space Virtual Reality 360*, *Voxelus, Colosse, Ocean Rift*, *ENTiTi Creator* or *AFrame,* among others.

In terms of research, the influence of this technology on education is evident. Several meta-analyses or systematic reviews (Merchant et al., 2014, Radianti et al., 2020; Villena-Taranilla et al., 2022; Wu et al., 2020) show some of the positive effects of VR on student learning. These effects are reinforced in the work of Gargrish and Mantri (2020), showing that this technology can increase motivation for learning, and provides a positive impact on academic performance, even in video-based teacher training (Richter et al., 2022), where self-efficacy has also been shown to be significantly more positive than implementing traditional systems.

It is a proven fact that the multimodal stimulation provided by these environments positively affects academic efficiency (Wang et al., 2021), so current teachers should take advantage of this reality to implement scenarios in which plans or regulatory frameworks are linked to these experiences, materialized in teaching methods and strategies adapted to the virtual experience, whose experimentation arouses greater interest and motivation, as well as better academic results.

Augmented reality in education

The conceptual beginnings of AR were pioneered by Caudell and Mizell (1992), who first defined the term as a technology that can increase a user's field of vision through additional information that facilitates the performance of tasks, thanks to computational processors that can transform and plot simple graphics in real-time. Azuma (1997), another of its pioneering authors, conceptualizes AR as a variation of virtual environments that facilitates a different view of reality that brings novelty to the user, through the superimposition of objects. In other words, it can be said that AR allows the combination of digital and physical information in real-time; that is, it adds an unreal object to a real context with superimposed virtual contents (Cabero-Almenara et al., 2018). To do so, it uses various electronic devices such as tablets, phones, glasses, or other HMD devices that allow both types of information (real and virtual) to coexist in order to facilitate the experience of new scenes that provide additional communication.

Going deeper into a terminological clarification of this concept, it is necessary to point out that there are scholars (Squire & Klopfer, 2007; Wu et al., 2013) who contradict the epistemological notion of AR as a technology, to understand it as a technique, since it is not only a technological artifact -a product-, but it also implies a resource that accompanies technology or makes use of it, so it has multiple functionalities that encompass procedures and protocols. From this point of view, AR could be defined as a novel technique supported by technology that allows users, depending on their own activity, to improve the vision of the real environment, through software that may or may not be ubiquitous and whose function is to overlap virtual information to that environment, in real-time, thus facilitating access to a mixed reality, which may be two-dimensional or three-dimensional in nature.

The operation of AR is made possible by four elements: a camera to capture the images of reality, a screen or output device to project the combination of real and virtual images, a processor to generate the virtual content, and an AR trigger that usually works through a location sensor that, together with the compass and accelerometer, orients devices, tags, and markers, giving rise to the virtualized environment. However, in addition to its basic operation, AR also presents some features that define and articulate its nature. Table 1 shows a customization of the works of several authors (Azuma, 1997; Cabero-Almenara, 2018), that synthesize the most important features of this technique.

Table 1: Main features of the augmented reality technique

Features of AR	
It operates in a mixed reality environment	The information generated thanks to this technique has real and virtual contents mixed, so that a hybrid reality is created, closer to the real world than to virtual environments.
Real-time integration	The creation of mixed content occurs in the present time and place; that is, live and about reality itself.
Activated in a real physical context	The additional information is directly related to the reality of the human eye, thus forming a much more complete perception of it in a physical reality environment.
Designed and displayed in several dimensions	AR can be designed and visualized in 2D and 3D, with the nature of the user's experience left to the user's choice.
It allows working with various formats	AR experiences can combine different digital objects: text, graphics, images, audio, video, 3D object or environment, websites, Cartesian coordinates, footprints, etc.
It enables human-machine interaction	The AR technique allows the user direct participation to interact with the information digitally, modifying the contents that he/she visualizes.
It modifies perceived information	Viewing augmented content can improve and change the quality of the perceived information.
It promotes active participation	As a technique that increases the perceived information through the user's participation, there is an interdependence that ensures new and better learning environments.

In recent years, design software that, through programming, allows the creation of new models and AR tools has been proliferating. Some of the most widely used are *Trimble SketchUp*, *Blender,* and *Autodesk 3ds Max*. Others such as *artoolkitX*, *MXRToolKit*, *Studierstube*, or *ARTag* have also shown their potential in many areas. We should also mention *AR-Media Plugin*, *ArUco*, *ATOMIC Authoring Tool*, and *BuildAR* (Cubillo et al., 2014). More recently, *Vuforia*, *Unity*, *Wikitude SDK* or *Meta Spark*, among others, stand out. All these resources are basically prepared for the creation of AR applications and, therefore, allow rendering actions, graphic design, registration tasks, modeling, and animation, both 2D and 3D.

Another step of AR is to bring this technique closer to the user through applications that are already designed or programmed to be implemented in all areas, without the need for programming knowledge. It is quite interesting to highlight some examples such as *QBox*, *Blippar*, *MetAClass*, *Metaverse*, *JigSpace*, *Plickers*, *Halo AR*, *ARitize-3D*, *Roar*, *Arloopa*, *Devar*, *UniteAR*, *LearnAR* or *Hope*.

Others such as *Junaio*, *TwittARound*, *Layar*, *WallaMe*, *WordLens*, *Aurasma*, *Lookator* and *HP Reveal* (all of them in disuse) were also implemented, as well as *Augment*, *Aumentaty Geo*, *Aumentaty Creator* and *Scope*, currently in force. More specifically, and especially in the sphere of High School, applications such as *ARcircuits 4D*, *SpaceCraft 3D*, *Arloon*, *LandscapAR* or *Estarteco* (de la Horra, 2018), as well as *ARGOplay*, *Elements 4D*, *Anatomy 4D*, and *Zookazam* have emerged strongly. On the other hand, for Kindergarten and Elementary School users, applications such as *ChromVille*, *Quiver*, *Flashcards*, *Planets AR*, *Devar* or *Dinos AR* which encourage children to learn in a playful and fully interactive way, also stand out.

Some systematic reviews have highlighted the use of AR scenarios in education (Akçayır & Akçayır, 2017; Athanasios, 2022; Bacca et al., 2014; Cheng & Tsai, 2013; Garzón et al., 2020; Gómez et al., 2020), pointing to an improvement in didactic processes and student learning. These studies indicate that the usefulness and motivation of this technique have not yet reached their peak and should continue to advance along with new practices in access to knowledge and the training of its users, taking into account new developments in technology and the rise of innovative studies. Yavuz et al. (2021) have also delved into the factors that affect the use and implementation of mobile AR, emphasizing among their benefits the ease of learning, the visual quality, and its simplicity of use. On the other hand, it has also been shown that AR as a mediating element can favor new learning strategies and improve motivational processes, including through the integration of theoretical models such as Biggs' 3P model or Keller's ARCS motivation theory (Chang, 2021; López-García et al., 2019), which also provide greater interest and learning effectiveness. In short, we see that these augmented environments provide enormous possibilities in the educational field. It is necessary to take advantage of the manifest potential to develop experiences that bring greater significance to the user experience.

Educational Robotics

In recent years, robotics has become considerably ubiquitous, playing a leading role in many of the activities of our daily lives. We are constantly interacting with robots and assigning them tasks that facilitate our work in the different fields in which we operate.

In the educational context, robotics, programming, and computational thinking are becoming increasingly widespread trends, especially because of the idea that the next generations will need to master them to be able to live according to the requirements of the future society. Seymour Papert, the father of constructionism, in an attempt to warn of the dangers of a society that merely consumes technology (Resnick et al., 2009), would go so far as to affirm that students must be taught to program so that they do not end up being programmed by devices (Blikstein, 2013).

Indeed, Papert is considered one of the pioneers of educational robotics. In 1967, he and his team created *Logo*, a programming language through which they intended that all students should learn to program from an early age by developing *procedural thinking* (Papert, 1980). It was not until the arrival of the new millennium, thanks to the spread of the concept of computational thinking, the birth of new, more user-friendly programming languages, and the arrival of more accessible robotic devices, that robotics, programming, and computational thinking became one of the most popular emerging technologies in the educational world.

The prevalence of computational thinking in today's educational landscape and the attention it receives is reflected in numerous meta-analyses and systematic literature reviews published in recent years (e.g., Merino-Armero et al., 2021; Tang et al., 2020). One of the most commonly accepted definitions of computational thinking is that developed by Jeanette Wing (2006) as an approach to "solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science" (p. 33). According to the same author, computational thinking is already today a fundamental skill for everyone, not only for computer scientists; thus, in addition to literacy and numeracy, computational thinking should be added to the skills to be acquired by children.

Among the different possibilities for implementing computational thinking in the classroom, two approaches stand out: unplugged activities and plugged-in activities. The first approach refers to a set of activities that do not require electronic devices, and that are intended and designed to promote computational thinking, especially in the early stages of cognitive development (del Olmo-Muñoz et al., 2020; Zapata-Ros, 2019). Conversely, plugged-in activities are those that involve programming exercises through technological devices such as computers or robots. It is easy to find plugged-in activities that make use of visual programming languages such as *Scratch*, *Blocky*, *Minibloq*, *Open Roberta*, or *Kodu* along with others that use more advanced, text-based programming languages such as *Python*, *C*, *Java*, or *Swift*. An example of the Scratch programming language is shown in Figure 3.

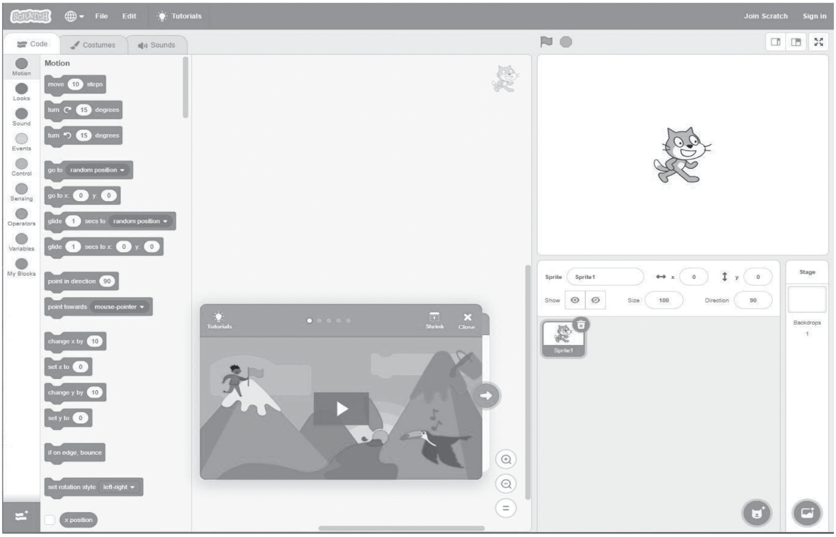

Figure 3: *Scratch programming language*

Note. Own work.

Many physically programmable robotic training sets such as *BeeBot*, *BlueBot*, *Kibo*, *Ozobot*, *mBot*, *Dash & Dot, Robo*, and *Lego WeDo / Mindstorms*, have also reached the classroom, allowing students to design and/or operate a robot from start to finish. Furthermore, educational initiatives in non-formal environments such as coding camps, workshops, challenges, or competitions with the potential to awaken children's enthusiasm for robotics are also becoming more and more frequent. Some of these robots are shown in Figure 4.

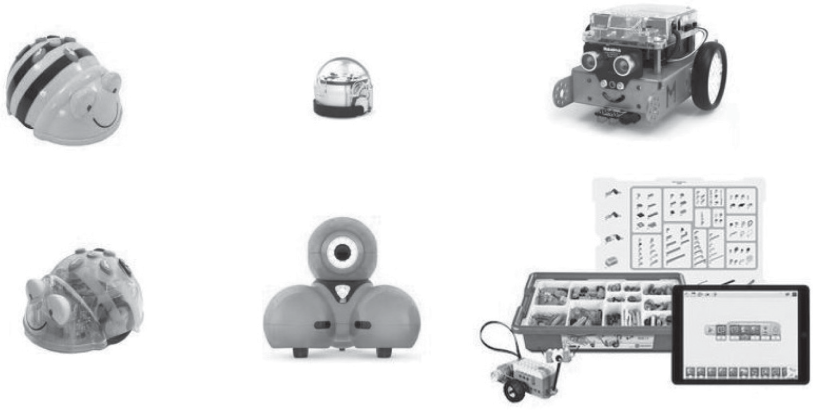

Figure 4: *Robotic training sets*

Note. Own work.

There are many definitions of educational robotics that can be found in the scientific literature. Ruiz Velasco (2007), for example, defines it as "the discipline that aims at the conception, creation, and implementation of robotic prototypes and specialized programs for educational purposes" (p. 123). While for Guasmayán et al. (2019) it is "the set of pedagogical activities that develop thinking skills in the student through the construction and programming of robots" (p. 19).

The implementation of educational robotics both inside and outside school environments has undergone a process of transformation and conceptual application that has evolved from a traditional version, which involved the development of technical knowledge based on the design, construction, control, and programming of robots (Barker & Ansorge, 2007; Talan, 2021), towards more innovative learning paradigms in which it is conceived as a learning system or context that relies on the use of robots to develop skills and foster the acquisition of competences in students, not exclusively in technical areas, but also in practically all curricular areas (Karim et al., 2015). Authors such as Gaudiello and Zibetti (2016) establish three learning paradigms related to educational robotics according to the hardware and software used and the interaction allowed by the robot: (1) learning robotics, when students use the robot as a platform to learn robotics from technical, production or engineering approaches; (2) learning with robotics, characterized by the use of robots as assistants/helpers that accompany teachers and/or students in the teaching-learning process; and (3) learning by robotics, in which the robot becomes a tool, at the service of teachers and students, to develop skills and promote the acquisition of content and competences from different disciplines. In this last learning paradigm, also known as robotic-based instruction, the robot becomes an active tool for teachers and students that mediates between all the dimensions of the educational process.

The literature has evidence that educational robotics can be incorporated to all educational levels, from K-12 to higher education (Talan, 2021). Regarding its pedagogical possibilities, it should be noted that benefits have been observed in students' academic performance (Athanasiou et al., 2019; Talan, 2021); the development of cognitive, affective, social, and metacognitive dimensions of learning (Catlin & Blamires, 2010); student engagement (Toh et al., 2016); teamwork (Menekse et al., 2017); interest and participation (Rubenstein et al., 2015); cooperative learning (Denis & Hubert, 2001), problem-solving (Zhang & Zhu, 2022); spatial abilities (Gonzalez-Calero et al., 2018); critical thinking and inquiry (Sahin et al., 2014); learning and transferring knowledge skills (Anwar et al., 2019); STEM skills (Eguchi, 2014), programming ability (Sun & Zhou, 2022), creativity (Zhang & Zhu, 2022), and motivation (Chin et al., 2014).

Moreover, there is a growing enthusiasm among the educational community for the use of robots in classrooms. In addition to the aforementioned interest among students, positive attitudes are also held by parents, who consider educational robots to be beneficial for their children's education (Lin et al., 2012); and by teachers, who perceive robotics as a very useful tool for the development of interpersonal and problem-solving skills of students (Khanlari, 2015).

However, some difficulties need to be considered. First, there are undeniable inequalities in the access to technology. Although in recent years the prices of technological devices related to educational robotics have fallen and institutional programs have been developed to provide these devices to educational centers, the access gap in rural or vulnerable environments continues to be a limitation for their spread. Initiatives such as *unplugged activities* can be an effective alternative to the scarcity of resources (del Olmo-Muñoz et al., 2020). On the other hand, it is also necessary to talk about the gender gap. Differences between boys and girls in the use of technology have been revealed through research from different perspectives such as motivation, interest, attitude towards technology, and intention to use, among others. Although more research is needed in this regard, didactic approaches that address more motivating alternatives for girls should be chosen (del Olmo-Muñoz et al., 2022). And finally, the gap in teacher training. Teachers exhibit knowledge, skill, and pedagogical gaps (Anwar et al., 2019), and this makes it necessary to promote teacher training so that they can successfully implement robotics for educational purposes. At the same time, it is important that such training provides teachers with the same formative experience that will later be brought to students so that they can get a complete idea of the implications and potentials it entails (Bocconi et al., 2022).

In short, educational robotics, programming, and computational thinking are trends that unite present and future. They go far beyond computer science or technology, as they foster fundamental skills for citizens of the 21st century (Moreno-Leon et al., 2018). Therefore, many countries are adapting their school curricula to promote the development of educational robotics, programming, and computational thinking as part of a broad and evolving definition of digital competence, which encompasses key skills for the future such as critical thinking, problem-solving, teamwork, creativity, or communication.

Conclusion

The educational technology industry is growing at a rapid pace. Every year more and more effort and money are invested in new technological developments that aim to become the ultimate educational tools. However, it has been shown that having the means, technical developments and even a good predisposition and knowledge of ICT is not enough for success. In this respect, it is necessary that teacher training goes far beyond technological, instrumental, or technical knowledge training. It is important to design this training from a practical approach that allows the interaction of content, pedagogy, and technology, so that teachers can effectively bring these new learning tools into the classroom.

We agree with Claro et al. (2017) on the issue of stressing that the involvement of school leaders is also necessary – on a large scale – in the pedagogical activities that demand a useful use of these technological resources. The education system today calls for policies that facilitate pedagogical innovation with these and other emerging technologies, given that any decision in technological matters that aims to transform education must be governed by progressively more advanced stages of integration of digital technologies in its pedagogical organization and the practical nature of its professionalization (Area et al., 2020). For this reason, educational communities must strengthen ties so that national and international demands converge in an idea of unity that can be easily extended to governments and institutions around the world to show a real commitment to consolidate emerging technologies in educational processes, whose efficiency in terms of educational quality – is quite evident.

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