

Article

Methodology for Modeling Virtual Reality Systems for Learning on Mobile Devices

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Abstract: The integration of new technologies in education has transformed learning processes, with mobile devices offering innovative opportunities for communication and engagement. Despite the potential of Virtual Reality (VR) in education, challenges persist, including limited adoption of devices in educational settings and the absence of a formal methodology for developing educational software tailored to VR. This study proposes a structured methodology for designing and developing VR systems for mobile-based learning, emphasizing the creation of immersive virtual environments through a three-phase approach. The methodology addresses these challenges by providing a systematic framework for VR educational software development. The results highlight the effectiveness of this approach in enhancing educational experiences, offering insights for educators and developers to advance VR-based learning solutions and bridge the gap between technology and pedagogy.

Keywords: Learning, Methodology, Mobile Devices, Virtual Reality

1. Introduction

Nowadays, it is increasingly common for people to use mobile devices in many daily activities, given their popularity, versatility and ease of use. Since the so-called smartphones and tablets were introduced to the market, the development of applications for these devices has accelerated and their hardware components have diversified, allowing their users to perform almost all kinds of simple tasks ranging from keeping their agenda to running applications connected to the Internet, thus becoming a part of daily culture [Virvou, Katsionis & Manos, 2005].

Although it has been popularly said that mobile devices have a harmful effect and even promote leisure, they also have positive aspects because they provide their users with the ability to improve the way they communicate and have access to a large amount of information that exists on the Internet, which makes them especially useful to promote learning and develop skills or increase knowledge. The portability, immediacy, ubiquity and adaptability that mobile digital devices allow, make them an alternative in the use of pedagogical tools, particularly making it possible for the development of some educational content to be implicit in the mechanics of the activities carried out, the game. and fun as part of the learning process.

The latter increases the motivation to learn since the educational software becomes more interesting, especially if its resemblance is similar to that of a computer game that

Citation: Serri Ismael Hamad. Methodology for Modeling Virtual Reality Systems for Learning on Mobile Devices. Central Asian Journal of Mathematical Theory and Computer Sciences 2024, 5(6), 609-618.

Received: 8th Sept 2024
Revised: 15th Oct 2024
Accepted: 22th Nov 2024
Published: 29th Dec 2024



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makes use of three-dimensional graphics. From an educational perspective, it has been proven that with this type of software it is possible to improve the understanding of complex and abstract information, as it can help a user to be able to process multisensory information and, in some way, support various learning styles. whether formal or informal, showing in a simplified way concepts that are difficult to understand. For some years now, new technologies have been analyzed and used to improve the learning process, including the so-called Virtual Reality (VR).

This discipline can be defined as a virtual world generated by computers in which the user has the sensation of being inside it, and depending on the level of immersion, he or she can interact with the objects of the virtual world to one degree or another [Parisi, 2016]. Its use in education has been discussed for a long time and until recently, the challenge to overcome had always been the same, the devices and software were unaffordable to popularize and massify them in educational institutions. However, today, given the technological advances of recent years, the differences between modern Virtual Reality compared to the concept of Virtual Reality presented two decades ago are notable, since the technology is finally at a stage in which it is can adapt to any mobile phone or tablet [Mustafa & Carl, 2015].

The introduction of Google Cardboard showed the public for the first time that any smart phone of this generation can become a Virtual Reality device with the help of the accelerometer and gyroscope, built into its standard hardware. The Google Cardboard acts as an HMD (Head Mounted Display), it is composed of a cut-out folding cardboard that contains two optical lenses, one for each eye, with which depth perception is possible. This device allows, with the programming of appropriate behaviors and mechanisms, interaction with objects in a virtual world. At this point, any user with a smart phone and a low-cost VR-HMD can enjoy the immersive experience of Virtual Reality applications through a new medium [LaValle, 2017].

Under this new panorama of Virtual Reality technology, it facilitates (i) the manipulation and analysis of complex and large systems through the use of three-dimensional models, (ii) the reproduction of algorithms that simulate the physical behavior of objects, people and situations. of real life, allowing the user to manipulate them from any angle and point of view as if it were a real world.

When a user practices their skills in a safe environment, a Virtual Reality application constitutes an excellent educational tool [Steuer, 1992] [Hashemipour, Farahani & Bal, 2011], combining these applications with the use of mobile devices, it can be increase school success, improve cognitive skills and, even more importantly, improve the student's attention and concentration in solving specific problems due to its playful nature [Duffy, Lowyck & Jonassen, 2012].

It is worth highlighting that the use of mobile devices in a classroom for teaching and learning must imply a paradigm shift in the design and practice of pedagogical and didactic strategies, as well as the teacher's roots in traditional learning methodology. According to UNESCO, there are currently at least six billion mobile phone subscribers, and for every person who accesses the Internet from a computer, two do so from a mobile device. This organization makes clear the potential of this type of devices to improve and facilitate learning, especially in communities where educational opportunities are scarce.

Given the spread and rapid expansion of the functionality of these technologies, they can be used to support the United Nations goals for Education for all:

1. Responding to the challenges of certain educational contexts.
2. Complementing and enriching formal education.
3. Making learning more accessible, equitable, personalized and flexible for students around the world [UNESCO, 2017]. Thanks to the mediation of mobile devices, commonly called M-Learning (ML), is constituted as a teaching and learning method that facilitates the construction of knowledge, the resolution of

problems and the development of diverse skills and abilities in an autonomous and ubiquitous manner, as described in the FRAME theoretical model, to design structured mobile learning scenarios [Scanlon, 2014] [Ally, 2009]. The FRAME model shows how technology gives rise to relationships in social and personal learning from a constructivist perspective, and in active and interactive participation.

As can be seen in Figure 1, the FRAME model, represented by a Venn diagram, establishes the relationship between the student, the device and the social environment, providing criteria for each individual aspect and the overlap between them, so that it conceives the M-Learning as a combination of interactions between students, their devices and surrounding resources (people, objects, environmental technologies, etc.) [Ally, 2009]. The recent resurgence of virtual reality technology driven by the constant development of mobile devices, now represents the possibility of implementing it in any educational or training environment that requires the learning and practice of procedures applied to real environments, whether inserted in an environment of adventure, strategy, sports, action, simulation or role-playing game, through the creation of VR software dedicated to the teaching-learning process [Virvou, Katsionis & Manos, 2005].

The degree of realism of an environment developed through a VR application makes them efficient tools that allow training to be made more flexible and adapted to the needs of people and their educational, professional or work environments, particularly if they are proposed as part of mechanics, social learning and collaboration between those who participate in an educational environment as unique as the one supported by mobile devices [Merchant, Ernest, Cifuentes, Keeney & Davis, 2014].

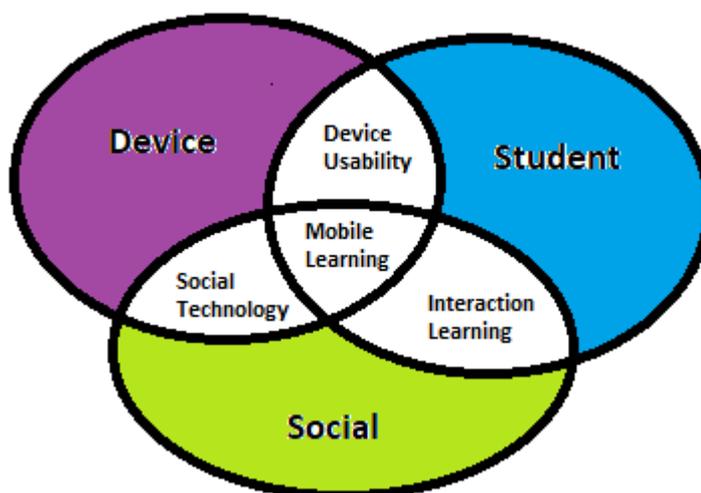


Figure 1. FRAME model.

There are different methodologies that focus on the creation of virtual reality applications. However, they do not look at the learning objective of the application, as they do not focus on the learning needs of the user, but on the correct development of the virtual world. Likewise, there is the SCRUM methodology, to quickly and flexibly manage a project, although it is not focused on the creation of virtual worlds or on the user's learning approach, but its processes include the Initiation, Launch phases. Review, Implementation, and finally, Planning.

As can be seen, these methodologies only focus on the determination of the visual components and interaction mechanisms, but the instructional design is absent. Therefore, this work proposes a methodology that aims to be a guide to integrate the development of the virtual world with the instructional analysis required in a learning environment with

the advantage of being implemented on mobile devices. A three-stage methodology is proposed, especially designed for the design of Virtual Reality educational environments called, Methodology for the Development of Educational Spaces for Virtual Reality (MDES FVR).

The structure of the article presents the phases of the proposed methodology, beginning with a general description of it, followed by the detailed explanation of each phase. Subsequently, a section showing the results that are intended to be achieved with the methodology. Finally, the conclusions of the work are presented.

2. Materials and Methods

The Methodology for the Development of Virtual Reality Educational Systems has been developed specifically to determine in detail the components of a three-dimensional environment modeled with Virtual Reality techniques for the creation of a learning system. It is specifically designed as an interactive playful environment where users can learn and experiment freely with objects and entities represented in a virtual world that is interacted with through a mobile device. MDES FVR also takes into account the interaction of users in an experimentation environment where knowledge of the specific disciplinary area is presented as content clearly structured by cognitive processes, raised based on the specific learning objectives described by the developer and a strategy. well-defined instructional.

Figure 2 presents the general phases of the methodology proposed in this work. In the first stage of this methodology, called Systematic Instructional Design, the structure of the environment is determined, carrying out an instructional analysis of the subordinate skills that are intended to be developed in the virtual environment. This design covers different steps that range from the description from the educational scenario, to the evaluation of learning. Specific aspects that allow the implementation of group work, implicit in the development of virtual world activities, are also taken into account.

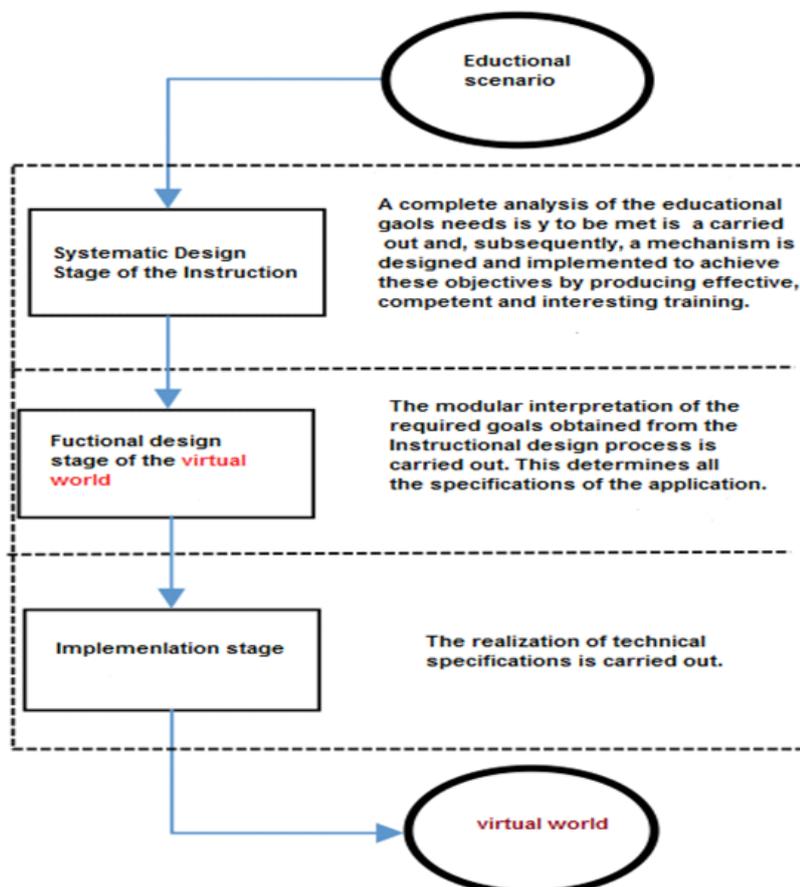


Figure 2. MDES FVR Methodology

In a second stage, the Functional Design of the system is carried out, based on the structure provided by the systematic design of the instruction. Such a structure can be considered as the requirements for the design stage where, among other things, the functions to be performed in the virtual world are specifically determined. This is where the modeling of the system or application and its different functions is carried out.

In the third and final stage, the technical specifications are carried out. This is where the characteristics and functional relationships between each element must be taken into account, taking special care to respect the established standard and the specifications obtained from the functional design. Figure 3 shows in detail the elements to be considered in the stages of the MDES FVR methodology, where it can be seen that from the compilation of the requirements for the systematic design of the instruction, that is, what is wanted to be done, the way in which how it is going to be carried out, creating a script that allows designing the artistic scenario that will be generated in 3D using different geometric modeling techniques, once finished and to give it a real appearance, environmental effects are applied. To establish the scenario-user interaction, it is necessary to implement different methods that guarantee this interaction. Finally, the virtual world is obtained that can be supported by different devices to be used in a teaching-learning process. Likewise, each of these stages is explained in the following subsections.

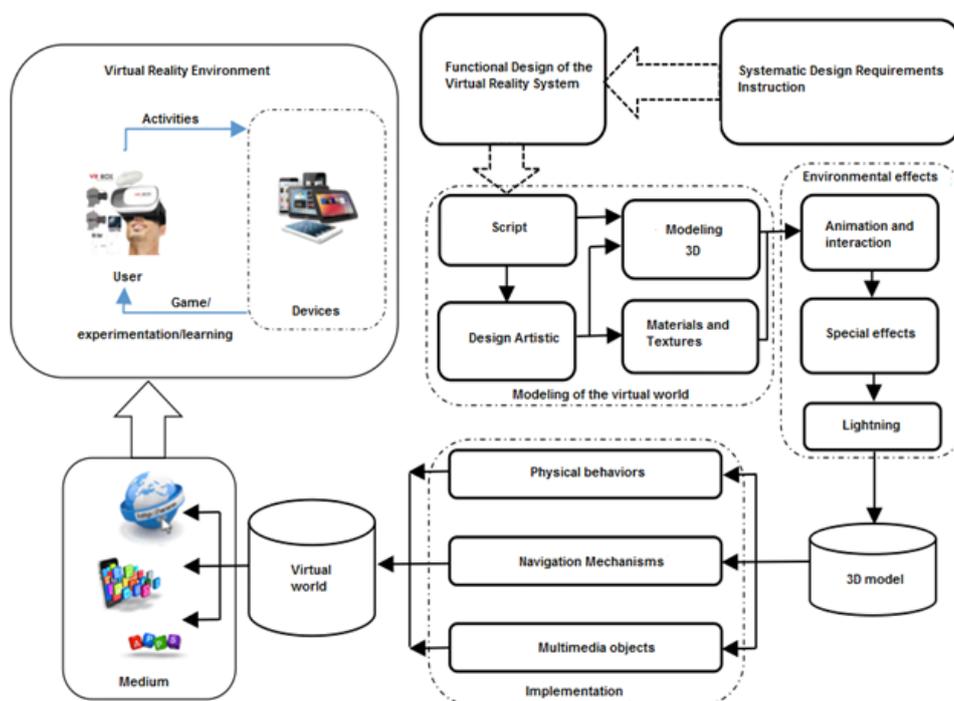


Figure 3. Detail of the MDES FVR Methodology

Systematic instruction design stage

It is clear that people learn in different ways. Such differences depend on many factors related to who they are, how they perceive themselves and how they interact with other people, among other things. Life experiences and the environment in which people live greatly influence the way they perceive and process information. The Human Information Processing (HIP) model arises in parallel with cognitive psychology, trying to explain how a person acts in a specific situation. The main interest of this cognitive approach focuses on describing and analyzing various processes and skills of this type, which guide the development of human thought such as perception, attention, understanding, thinking, representation of knowledge, memory and language, among others [Bruning, Schraw & Norby, 2012]. In the MDES FVR methodology it is stated that

users attribute their own knowledge based on their cognitive structures and processes, without explaining how these elements are initially constructed.

The design stage proposed in this methodology clearly describes the existence of a predictable and reliable relationship between a stimulus provided by the teaching materials and the response that occurs in a student when learning them. That is, the designer has to identify the competencies and skills that the student must master according to the learning area of the virtual world to be developed. In this phase, the current situation is determined, to have a general overview of the educational scenario and depending on its characteristics, the instructional requirements are determined which serve as entry to the functional design stage.

When determining instructional requirements, aspects such as the human and material resources available and the target population to whom it is directed are also considered. Once the instructional requirements have been determined, a detailed instructional analysis is carried out, in which the learning objectives that are intended to be achieved with the instructional material to be developed are specifically determined.

To achieve such objectives, it is necessary to make an analysis of the skills and subordinate abilities that you want to develop. Such instructional analysis provides the functional design phase with a series of specifications that must be taken into account to correctly choose the strategies and instructional means that will allow determining the workflow, development tools and information technologies that will be used in the implementation phase of the instructional material.

Functional design stage of the virtual world

From the systematic design of the instruction, it must be considered that the student or user does not attend classes at a certain place and time, their learning is carried out during the execution of activities in a mobile application, which can well be used with first-hand immersion. person using the Google Cardboard or on the screen of the mobile device. Taking this configuration into account, the teacher or facilitator, instead of directly attending to the teaching, takes the role of advisor and counselor in the individual educational process, proposing activities or challenges to the participant in the recreational environment, as can be seen in the figure. 4.

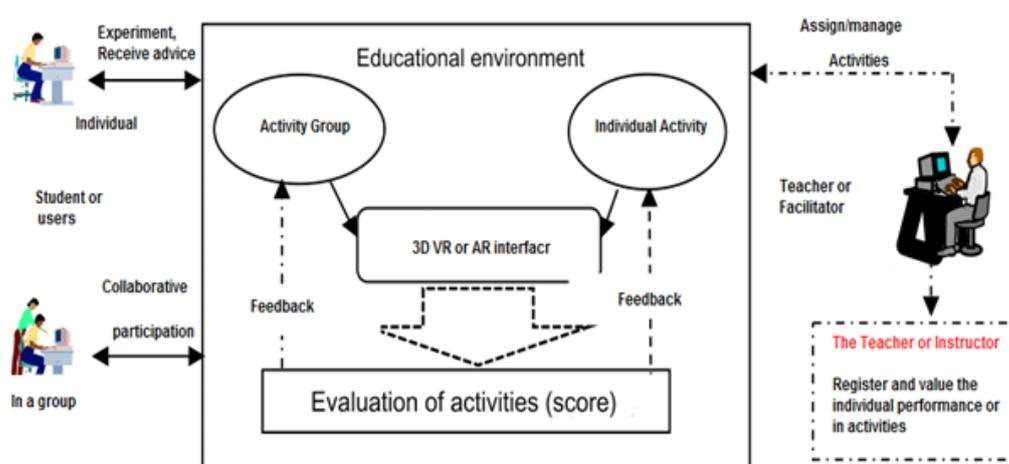


Figure 4. Functional Design of the virtual world

Knowledge, traditionally stored in books, is implicit in an interface constructed as a virtual scenario containing three-dimensional simulations modeled with virtual reality techniques, as well as text and online help provided by the facilitator. It is important to consider that communication through the Internet allows for the promotion of

collaboration and advice by putting each student or participant in contact with other participants or with the teacher or facilitator who, in this case, plays a fundamental role.

Implementation stage

The development life cycle of a Virtual Reality system defined within the MDES FVR methodology comprises a series of steps that focus on the requirements obtained from the systematic design of the instruction and the analysis of the system's functionality. As can be seen in Figure 5, these two stages represent the first steps in the life cycle of the methodology, to continue with the implementation. Finally, at this stage it is necessary to consider an evaluation as a fundamental element to improve the quality of the knowledge and skills of the student or participant.

This must consider, in a comprehensive manner, all the tasks that the student performs, such as group participation, interactions with the facilitator or other participants, consultations made and experimental work, among other things, all through the registration of a score. This process must take into account all the elements found in the previous stage and that intervene in the learning of the student or participant. Additionally, it must be personal, in terms of what needs to be done for each student, and lastly, it must be continuous, because it has to consider the student's history throughout the process.

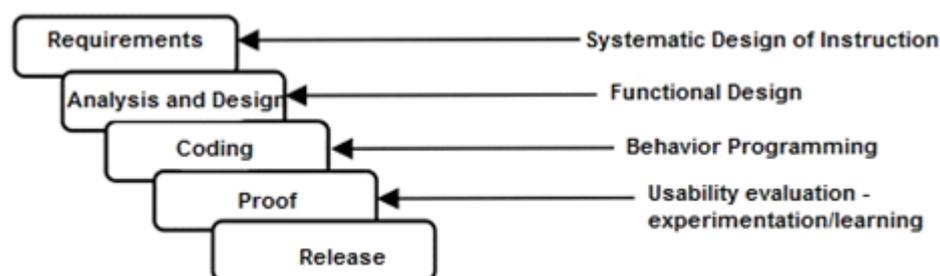


Figure 5. Life cycle for the development of virtual worlds with MDES FVR

From the functional design, it is possible to model a virtual world including any effect of a VR environment that is required. The result of this step is a three-dimensional model to which physical behaviors, navigation mechanisms and the insertion of multimedia components are assigned that complement the virtual world, which is the one that will be presented to the user. The virtual world created is stored on a mobile device as a standardized application that has stereoscopic effects and is navigable through the kinematics of the human body through its accelerometer and gyroscope.

To do this, it is necessary to have an inexpensive headset and headphones. This minimal equipment allows the user to experiment and carry out activities in the environment presented to them. To develop this stage, the proposal for a flexible architecture based on a graphical interface for mobile devices that uses a set of application programs and programming languages that are standardized to interact in development with the Google SDK is presented in Figure 6. Cardboard [Google-VR, 2017]. This architecture allows you to take advantage of the features of the C#, JavaScript, HTML 5 and Python languages, as well as the capacity of smart phones or portable and home consoles [Reality, 2017] [Unreal, 2017].

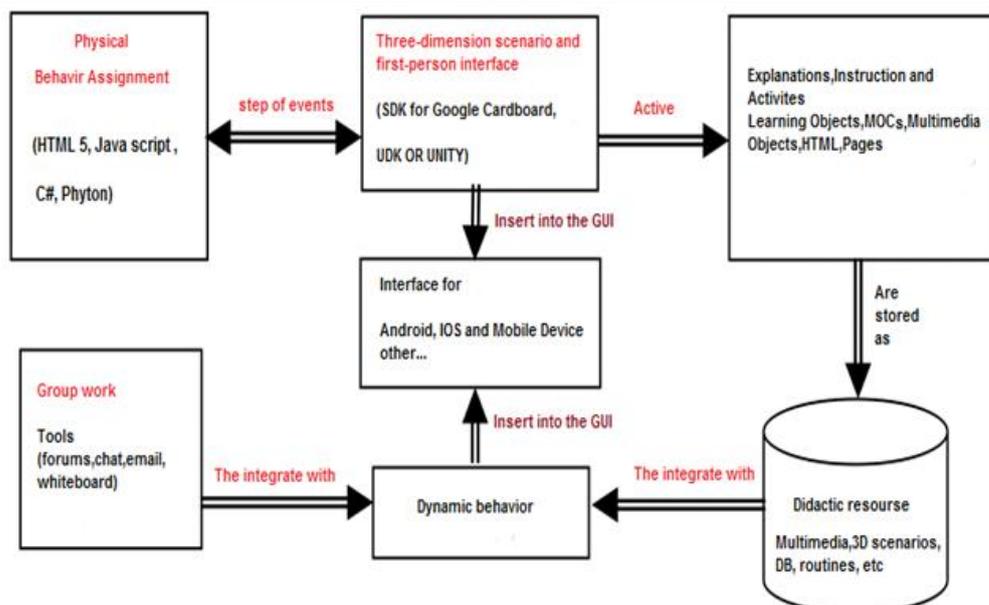


Figure 6. Architecture for Virtual Reality systems with MDESFVR

3. Results

The MDESFVR methodology allows the creation of virtual worlds for learning on mobile devices through the application of three stages, these being: systematic design of the instruction, functional design of the virtual world and its implementation. The results of the analysis in the first stage constitute the prerequisites for the functional design of the application and clearly determine the workflow, the development tools and their functionalities and interactions based on the identified needs. At this stage, all the elements involved in the teaching-learning process that is intended to be modeled must be specified. In addition, both human and technological resources, necessary for the correct functioning of the virtual world.

Functional Design, the second stage of the methodology, is used to give meaning to the operation and objective of the product to be created, which must be (directly or indirectly) satisfactory to the needs of the end user, as well as the requirements of the teaching process. -learning to consider. Working on a functional design means clearly and precisely describing the objective of the functionality of each object in the virtual world, given that it is part of the specifications that it must include and that are evaluated through some test, such as the one proposed by Nielsen & Pernice [2010].

In the third and final stage, the strategies for the implementation of the educational scenario at the macro and micro levels must be taken into account, that is, taking into account the characteristics that the application must meet and the type of work that will have to be carried out to achieve the instructional goals, defined in the first stage of the methodology. Finally, the method and tool must be chosen to evaluate the work of each participant who uses this instructional material, either individually or when doing so in a group.

4. Discussion

It is noteworthy that, in the modern lifestyle, many or most of the young people are users of digital technologies such as computers, cell phones, smartphones or tablets. The use of these devices is widely spread in modern society, since it allows them, among other

things, to stay informed with an Internet connection, perform simple tasks such as sending email or messaging, watching video tutorials or playing video games, and participating in virtual communities. However, many of the current educational systems continue to consider traditional methods to develop and strengthen learning in their students with practices that include written exams, oral presentations, interactive presentations with slides, readings and summaries which are far from being as efficient as the sources of information to which young students have access and the technologies they use almost daily.

The current trend towards the use of mobile devices in education is focused on the fact that, in the future, these devices will increasingly be used in classrooms and educational and cultural centers. The appearance of these devices, originally designed for communication, has introduced a paradigm shift in Education in general and in Distance Education in particular. The use of mobile devices in education is a fundamental element in the construction of knowledge, since with the use of these technologies the possibilities of interacting with group members increase, communication is improved; and therefore, the barrier that separates teachers from students is blurred.

The portability, immediacy, ubiquity and adaptability that modern digital devices allow, make an application on a mobile device a good alternative as a very effective pedagogical tool, particularly if the user has as its main idea an environment where educational content is implicit. in the mechanics of the activities carried out in an interactive process. The virtual world created acts as a mediator in the learning process, always monitored at all times by a teacher who is in permanent contact with the users, promoting collaborative work with other users, planning the activities and serving as a knowledge facilitator.

For a collaborative virtual reality playful environment to be truly effective, the use of a methodology that encompasses the entire planning for the complete development of a virtual world that guarantees user learning of a specific teaching process must be considered. For this, the MDES FVR methodology is proposed, in which systematic instruction design strategies must be considered so that the user learns more easily thanks to the stimulation achieved by interactive processes, experimentation and joint work with other users, defined in the functional design of the virtual world. It is important to highlight that implementing individual or collaborative activities in a virtual setting will allow individuals to master certain tasks that they were not able to perform before.

5. Conclusion

In conclusion, the proposed MDES FVR methodology offers a structured and effective approach for the development of Virtual Reality-based educational systems on mobile devices, providing a clear framework for instructional design, functional development, and implementation. The findings demonstrate that by integrating interactive, immersive virtual environments with mobile technology, learning processes can be significantly enhanced, promoting engagement, collaboration, and deeper understanding of complex concepts. This approach has important implications for educators and developers, offering a pathway to leverage VR in educational settings to address diverse learning needs. Further research should explore the scalability of this methodology across various disciplines, investigate its long-term impact on student performance, and examine the potential for incorporating emerging technologies, such as augmented reality, to further enrich mobile learning experiences.

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