A Review On The Analysis Of Qoe Applied In Serious Virtual Reality Games

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Abstract. Over time, electronic games have evolved from simple pixelated objects to complex experiences with a wide variety of narratives and user interactions, including various forms of immersion such as customized controls and games utilizing virtual reality (VR). VR allows users to interact with and perceive virtual objects in a more immersive way. Transitioning beyond mere entertainment, games have proven to be excellent educational tools for teaching various subjects and assisting in tasks like professional training across diverse fields, known as serious games. Through the use of virtual reality, individuals can visually learn through experiences such as virtual trips to aquariums, museums, and even the lunar surface. Healthcare professionals can practice surgical techniques using virtual patients, and production industry workers can operate machines without the need to halt real factory machinery for training purposes. While this technology is considered revolutionary by some, certain factors still hinder the widespread adoption of virtual reality by the general population. One primary concern reported by VR users is the occurrence of motion sickness and discomfort. Research is underway to enhance the user experience, but this remains an open challenge. Addressing this issue, user experience (QoE) research can be applied to assess and identify improvements. Thus, QoE enhancements not only contribute to user satisfaction but also maximize the educational benefits of these games. This study aims to evaluate key user complaints regarding the experience with specific games. Once these issues are identified, suggestions will be implemented, and a new round of user game experimentation, along with feedback collection, will be conducted. This refinement process is intended to be repeated iteratively, allowing the results to guide improvements in the Quality of Experience for serious games.

Keywords: Quality of experience. Qoe. Virtual reality. Serious games.

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1 Introduction

Digital games, an interactive form of electronic entertainment, have secured a significant place in contemporary leisure and global popular culture. These audiovisual experiences allow players to interact with virtual environments, responding to visual and auditory stimuli [1, 2]. They come in various formats and genres, catering to a wide range of preferences and interests.

Among the most popular types are online games, which enable players from different parts of the world to interact in shared virtual spaces. These range from massive multiplayer competitions to cooperative adventures, offering a dynamic and engaging social experience.

Simulation games aim to replicate real-world aspects, allowing players to experience scenarios from city management to everyday life simulation. They provide a playful experimentation field, exploring different

aspects of life and complex system operations.

Augmented reality has introduced a new dimension to digital games, blending virtual elements with the player's physical environment. This technology creates a unique immersive experience [3, 4], blurring the lines between reality and virtuality, and expanding gameplay possibilities.

Beyond entertainment, digital games have also found a significant role in education and training, known as educational or "serious games". Designed to teach, train skills, or convey specific messages, they effectively combine game elements with educational content. These games are effective in various contexts, from classrooms to corporate training and medical simulations.

The digital gaming industry, encompassing everything from large productions to independent projects, continues to grow and diversify, reflecting and influencing cultures and trends worldwide. This industry shapes not just how people entertain themselves but also how they learn, connect, and experience the virtual and real world.

1.1 Serious Game

A "serious game" is a type of electronic game designed for purposes that extend beyond mere entertainment. These games are created with specific educational, training, awareness, or simulation objectives, differentiating them from traditional games that primarily focus on entertainment and fun.

Serious games are often used in educational, corporate, military, healthcare environments, and in training for various skills. They combine learning theories, game design, and often interactive technologies to create experiences that are both engaging and instructive.

For instance, a serious game might be developed to teach business management skills, train medical procedures, educate about environmental issues, or simulate emergency response situations. The central idea is to use the engaging and motivating elements of games to achieve specific learning or training objectives, offering a more interactive and practical alternative to traditional methods of education and training.

1.1.1 A Brief History

The concept and practice of serious games have a rich and diverse history, reflecting the evolution of gaming technology and changes in educational and training needs. Over the past decades, different games for various educational purposes have been created, some notable examples include:

1960s and 1970s: Early Steps Military and Flight Simulations: The origin of serious games is often traced back to military and flight simulations. These were used to train pilots and military personnel in realistic scenarios without the associated risks of actual training. Strategy and Management Games: Games like "The Oregon Trail" (1971) and "Lemonade Stand" (1973) are early examples of games with educational objectives, teaching about American history and business fundamentals, respectively.

1980s: Expansion and Popularization Education and Entertainment: Educational games became popular, especially for children, with titles like "Where in the World is Carmen Sandiego?" (1985), which taught geography and history.

1990s: Advanced Technology Virtual Reality Simulators: With the advent of more advanced technologies, serious games began to incorporate virtual reality and more complex simulations. Corporate and Professional Training: Companies and other organizations started using serious games for training and skill development.

2000s: Digital Expansion and Social Awareness Online and Multiplayer Games: The internet enabled the development of online and multiplayer serious games, expanding their reach and impact. Games with Social Themes: Games began to be used for raising awareness about social issues, health, and the environment, such as "Darfur is Dying" (2006), a game about the crisis in Darfur.

2010s to Present: Integration and Innovation Augmented Reality and Mobile: Games like Pokémon GO have shown how augmented reality can be used for educational and engagement purposes. Gamification in Various Sectors: Gamification, or the application of game elements in non-gaming contexts, has become a popular strategy in education, health, marketing, and more.

1.2 Virtual Reality

Virtual Reality (VR) is an innovative technology that transforms the way we interact with digital environments and extends the boundaries of our sensory experience. Essentially, it creates a simulated environment presented to the user in such a way that they feel immersed in this artificial world. Using specialized devices, such as VR headsets, sensor-equipped gloves, and even full-body suits, users can see, hear, and in some cases, touch and interact with a three-dimensional virtual environment.

Unlike traditional media where the user is an external observer, virtual reality provides a first-person experience, placing them inside the virtual environment.

This opens up a vast array of applications, ranging from entertainment and gaming to training, education, medical therapy, and exploration of environments inaccessible in the real world.

As technology advances, virtual reality continues to offer increasingly realistic and immersive experiences, challenging our perception of what is real and what is digital. This rapidly evolving field promises not only to transform our leisure experiences but also to have a profound impact on various industries, changing the way we learn, work, and interact with the world around us.

Serious games with Virtual Reality (VR) represent a significant advancement at the intersection of technology and education. Utilizing the immersion provided by VR, these games create three-dimensional virtual environments where users can interact in an intuitive and engaging way. This approach transforms the way learning and skill acquisition are perceived, making them more dynamic and interactive, and allows users to experience scenarios and concepts that would be difficult or impossible to replicate in the real world. Besides improving information retention and understanding of complex concepts, serious games in VR can also increase motivation, making the learning and training process more appealing and fun. They offer a unique platform for personalized and adaptive experiences, catering to a variety of needs and objectives in areas such as education, training, healthcare, and beyond.

1.2.1 Tools used in the development of VR applications

The development of serious virtual reality (VR) games is an area that combines advanced technology with pedagogical principles, and for this, a series of specialized tools are used. Among the most fundamental are the game development engines, such as Unity and Unreal Engine. These platforms provide the environment where developers create, test, and refine their games. Unity is particularly appreciated for its user-friendly interface and broad compatibility with VR devices, making it ideal for educational projects. Unreal Engine stands out for its impressive graphics and rendering capabilities, which can be crucial for creating more realistic VR experiences.

The development of educational virtual reality (VR) games in Unity and Unreal Engine is a dynamic field that combines cutting-edge technology with innovative teaching strategies, each with its unique characteristics and advantages.

Unity is often chosen by VR educational game developers due to its intuitive interface and versatility. One of the main advantages of Unity is its ability to support a wide range of VR platforms, making it a flexible choice for projects targeting different VR devices. Additionally, Unity has a vast library of assets and plugins available in its online store, which facilitates the integration of ready-made elements and accelerates the development process. With an active community and abundant learning resources, both beginners and experts can easily find support and guidance. Furthermore, Unity enables efficient integration of interactive and pedagogical elements, crucial for creating immersive educational experiences.

On the other hand, Unreal Engine is known for its impressive graphics and advanced rendering capabilities, ideal for creating realistic and visually stunning VR environments. This engine uses the C++ programming language and its visual scripting system, Blueprint, allowing developers with less programming experience to build complex game logics more intuitively. Unreal Engine is particularly suitable for projects requiring a high level of visual detail and realistic environmental effects, features that can significantly increase engagement and immersion in educational VR games.

Both platforms offer robust resources for creating immersive learning experiences, such as support for motion tracking, spatial audio, and realistic physical interaction. However, the choice between Unity and Unreal Engine often depends on the specific preferences and experiences of the development team, as well as the specific needs of the VR educational game project. Unity tends to be more accessible for beginners and projects with tighter budgets, while Unreal Engine is ideal for projects seeking a high level of graphical fidelity and visual effects. Regardless of the choice, both engines are capable of producing effective and engaging VR educational experiences, opening new horizons in the field of digital education.

Moreover, the development of educational VR games requires the use of 3D modeling and animation software, such as Blender, Maya, or 3ds Max. These programs are essential for building the visual elements of games, from detailed characters to immersive virtual environments. The ability to create rich and engaging visual elements is crucial for keeping users engaged and facilitating the learning process.

Another critical component in VR game development are the Virtual Reality Software Development Kits (SDKs). Examples include the Oculus SDK and the SteamVR SDK, which provide resources to optimize games for different types of VR headsets and con-

trollers. These SDKs are essential for implementing functionalities such as motion tracking, spatial interaction, and support for spatial audio, which are crucial for an immersive and interactive VR experience.

Besides these technical tools, the development of educational games in VR also involves a deep understanding of pedagogical principles. This includes the integration of educational strategies, such as game-based learning and gamification, to ensure that games not only engage users but also provide real educational value. The combination of these tools and pedagogical approaches allows for the creation of VR learning experiences that are both engaging and instructive, opening new possibilities in the field of education.

1.2.2 Accessories used in VR simulations

Virtual reality users have at their disposal a wide range of items, whose sophistication and price vary considerably. On the more expensive end are high-resolution virtual reality headsets. These devices offer immersive experiences through high-resolution screens, advanced motion tracking, and surround audio, as exemplified by models like Oculus Rift, HTC Vive, and PlayStation VR. These are often accompanied by motion controllers, which allow for more natural and intuitive interaction with the virtual environment. Additionally, tracking sensors such as cameras and position sensors are used to capture the user's precise movements, enhancing immersion.

For users seeking a more immersive experience, there are virtual reality platforms that allow walking or physically moving within a confined virtual space. These systems, while offering deep immersion, are generally more expensive and require more space.

On the other end, aimed at users with a more limited budget, are affordable virtual reality headsets, such as the Google Cardboard. Made of cardboard, these headsets use a smartphone as the display. The user simply inserts their smartphone into the device, where simple lenses provide the virtual reality experience. Although this option is less sophisticated in terms of visual quality and tracking, it makes virtual reality accessible to a wider audience.

Besides these main items, there are various accessories that can enrich the virtual reality experience. Items like headphones for more immersive audio, haptic gloves for tactile feedback, and treadmills to simulate movement in virtual space, while not essential, add additional layers of realism to the experience.

This variety of options allows virtual reality users to choose the level of immersion and interactivity that best suits their needs and budget, making the technology accessible and appealing to a wide range of people.

1.3 Fundamentals of Quality of Experience (QoE)"

Quality of Experience (QoE) is a concept that refers to the overall assessment of a user's experience when using a product or service, especially in digital and telecommunication contexts. Unlike Quality of Service (QoS), which measures technical aspects like speed and reliability, QoE focuses on the end user's perception and satisfaction.

QoE encompasses a variety of factors, including ease of use, visual or auditory quality, interaction efficiency, and even emotional content and engagement. For example, in video streaming, QoE doesn't just depend on the absence of interruptions or image quality, but also on how engaging and satisfying the viewing experience is.

Essentially, QoE is a comprehensive indicator that helps developers and service providers understand and improve how users interact with and react to their products or services.

1.3.1 QoE Applied to Games

Quality of Experience (QoE) in games is a crucial aspect that encompasses the overall perception and satisfaction of players with a video game. This assessment covers a range of factors that go beyond the mere technical aspects of the game, focusing on how the game is perceived and the enjoyability of the gaming experience for the user.

Among the elements that influence QoE [5, 6, 7, 8] in games, technical performance is fundamental. This includes graphical quality, loading times, latency in online games, and software stability. Gameplay also plays a central role, with fluidity, intuitiveness, and originality being essential aspects for a positive experience. In addition, the narrative and immersion of the game are important, with captivating stories and engaging game worlds providing a richer and more memorable experience.

Interactivity and socialization are especially relevant in multiplayer games, where the ease of interaction with other players and the quality of the community can significantly impact the experience. Finally, the ability to customize and a rewarding progression system are factors that contribute to high QoE, elevating the level of engagement and satisfaction of players.

Thus, QoE in games is a multifaceted metric [9, 10, 11] that encompasses everything from technical performance to subjective elements like engagement and en-

joyment, being a key indicator for the success of a game in the market.

1.3.2 Quality of Experience in Serious Games with Virtual Reality

Quality of Experience (QoE) [12] is a concept that assesses a user's subjective perception of their interaction with a service or product, particularly in the digital context. Unlike technical performance metrics, QoE encompasses factors such as user satisfaction, usability, and overall quality perception. This assessment is influenced by various variables, including user expectations, usage context, and interface design, making it a comprehensive indicator of the user's overall experience.

When applied to games, and more specifically to Virtual Reality (VR) games, QoE takes on a more complex and challenging dimension. In VR games, QoE is not just about gameplay and graphics, but also about immersion and user interaction with a three-dimensional virtual environment. The way VR engages the user, creating an immersive and convincing experience, and its ability to intuitively react to user actions, are crucial for a positive gaming experience. Success in creating an engaging and responsive virtual environment is key to QoE in VR games.

In the context of educational VR games, QoE plays an even more specific and critical role. These games aim to combine education with entertainment, where educational effectiveness - how the game facilitates learning and knowledge retention - is a key aspect of QoE. VR's ability to create realistic and engaging simulations can transform the learning experience, making it more interactive and memorable. Therefore, for educational VR games, high QoE means not only enjoyment but also effectiveness in conveying knowledge and skills, playing a vital role in modern education.

2 Theoretical review

Currently, the electronic gaming industry is evolving more and more. It is believed that about a third of the world's population plays some game and generates billions of dollars annually [13]. A few decades ago, games were simple and had few ways to interact, many were made up of a few pixels on the screen and have evolved into interactive virtual worlds and emotional narratives, driven by technological advances in computing and communication [14]. Different types of games have been and are being created to cater to different audiences and with different applications. In the scientific field, many studies are also done on games and in the vast content available in recent literature, we can highlight some works in the field of online and cloud games.

Online Games: this type of game has become a great leisure option in recent years, connecting thousands, or even millions of players in real time and providing players with various social experiences, from player combat to cooperation to achieve objectives within games [15]. In this type of game, research can be found aimed at improving communication between the player and the server [16].[17] present a new load balancing architecture for MMO games based on multi-server clusters. The proposed architecture and algorithm are validated through preliminary simulation experiments, indicating a high user coverage rate and an evenly distributed load in terms of client proportion on the servers, even under stringent gaming conditions. Studies can also be found focused on the social behavior of players who play and thus interact with other people within games, such as [15] who researched how interaction with other players improves social experiences and leadership skills within the game. There is also research for Metaverse games which are online games with an environment made with virtual reality [18] and works that explore the senses of hearing [19]or even smell [20].

Cloud Games: not all players can acquire hardware that allows them to play the latest games with satisfactory quality, in view of bringing their games to more people, companies have been developing ways to allow players to play on simpler devices, such as televisions, cell phones, and TV boxes. Such a feature means that the games are processed on powerful servers and sent directly to the player's screen, which needs to have sufficient processing just to at least display the game images on the screen and capture the controller data [21]. This way of playing has challenges such as improving data traffic between the player and the server, studies have been done, for example, to assess the player's experience on 4G [22] and 5G [23] and [24] networks.

2.1 Fundamentals of Serious Games

The integration of technology into the learning process can enhance the quality of education. One way to achieve this integration is through game-based learning, which leverages students' enthusiasm for such content. Thus, the use of elements from popular games can be utilized in an educational manner [25].

The integration of technology in education, especially through games, improves the quality of teaching and motivates students. Using elements of popular games, such as mobile games and augmented reality, in educational contexts, enhances the learning process. According to [25], serious games are becoming an alter-

native to the traditional method of education, improving the quality of the teaching experience. The interface of serious games allows for good exploration between virtual and physical environments and promote good sensory stimuli in the user.

2.1.1 Relevant Examples and Use Cases

The evolution of serious games in various areas, from education to corporate environments and museums, stands out as a significant trend in recent studies [26] and [27]. The integration of gamification in higher education has shown a positive impact on engagement, learning effectiveness, and student satisfaction, suggesting a more dynamic and interactive approach compared to traditional methods.

Specifically, the correlation between fun and satisfaction with user experience in serious games proved to be fundamental for effective learning in children, highlighting the ability of serious games to efficiently combine entertainment with education[26].

Furthermore, the application of mobile technology in museums, using serious games for experiential learning, revolutionizes the way knowledge is transmitted and received in cultural environments. These games promote a deeper interaction with the exhibits, encouraging a more robust retention of the information presented. This innovative approach not only engages visitors of various ages but also connects digital generations with historical heritage in an interactive and engaging manner. [28].

2.2 Quality of Experience in Games

The concept of QoE, or Quality of Experience, refers to a user's subjective evaluation of the overall experience when using a service or product, especially in digital contexts, such as video streaming, online gaming, or internet browsing [29].

Quality of Experience (QoE) is a central concept in interactive digital environments, particularly significant in sectors such as online gaming, virtual reality, and streaming services.

In the literature on QoE in games, besides the expected studies on the game interface itself, various topics are addressed. These include Cloud Games where games are processed on remote servers and sent over the network to the player's screen. In this area, the efforts of major companies that launched powerful platforms like Google Stadia, Nvidia GeForce Now, Microsoft xCloud, Sony PlayStation Now, among others, to attract players, are also highlighted [30]. Improvements in video frame rates and the latency of these frames have been discussed in reference [31].

MMO Games are client-server type games, where people interact with each other usually through characters within the game, and such games can have thousands of players connected at the same time [32].

Metaverse Games, in addition to the online characteristics of the previously mentioned games, present an expansion in the actions and senses of the players, increasing the game's immersion capacity, allowing the player to even simulate, for example, physical education classes [33].

2.2.1 Differences and Relationships Between QoE and Quality of Service (QoS)

Quality of Experience (QoE) and Quality of Service (QoS) are fundamental concepts in telecommunications and the internet, but with distinct focuses. QoE concentrates on the user's subjective perception and experience regarding a service or product, assessing factors such as satisfaction, ease of use, and meeting expectations. On the other hand, QoS is more technical and measurable, focusing on the objective performance of the service, such as speed, reliability, latency, and packet loss. While QoS can be quantified by technical parameters, QoE is influenced by the user's personal and emotional interpretation, making it more subjective and variable.

Quality of Experience (QoE) links the perception and expectations of users to the performance of applications and networks, represented by Quality of Service (QoS) parameters. Establishing quantitative relationships between QoE and QoS is crucial to create effective QoE control mechanisms based on measurable QoS parameters [34].

2.3 Virtual Reality

The term Virtual Reality (VR) refers to an advanced interface for computer applications that allows users to interact with and perceive a three-dimensional simulated environment through multi-sensory devices. VR encompasses three main concepts: immersion, interaction, and engagement. VR began with the flight simulators used by the U.S. Air Force after World War II. Over time, VR has been applied to movies, games, and simulations for learning purposes [35]. There are also social virtual reality systems that enable multiple users to meet in a shared virtual environment [36]. Research indicates that different types of content can be taught and used for worker training in VR environments.

2.3.1 Importance of Virtual Reality in Serious Games

In the context of Virtual Reality (VR), serious games emerge as valuable tools in the assessment of memory and cognitive abilities, offering a more immersive and intuitive medium compared to traditional assessment methods. Although studies show that VR games may not have a direct correlation with conventional cognitive assessment methods, they are highly tolerated and intuitive, indicating significant potential for more engaging assessments [37].

Thus, the use of serious games in various educational and professional spheres reveals significant potential for the development of more engaging, interactive, and tailored teaching and learning methods suited to the needs of digital generations [25].

Not only subjects that involve memorization and reasoning can be taught, but also subjects like physical education and vocational education. In [33], the authors integrated virtual reality and AI for teaching football. Results showed that the quality of teaching was improved compared to traditional approaches.In [38], the authors created a training environment for the control of electrical substations that offers a high level of immersion for users. [39] constructed a virtual training system for industrial environments capable of demonstrating various everyday industry processes, thereby enhancing safety and production quality. [40] presented a training environment designed for paramedic training in multi-user settings. To create a useful learning environment, they assessed and improved user navigation, interaction, visual abstraction level, and task abstraction level.

[41] highlight the application of Serious Games in various areas, with a focus on a virtual reality game for mental health treatment. To ensure the game's effectiveness, the methodology developed and named iPlus, centered on the user and involving experts in disability, pedagogy, and game design, is used in the construction of the recreational therapy game. iPlus allows the creation of Serious Games in a participative and user-centered manner. Other works on virtual reality serious games can be found in the literature such as [42], [43], [44], [45], and [46].

2.3.2 Technical Challenges and Limitations of Virtual Reality

A challenge for virtual reality applications stems from the impacts on the human body, as seen in [47], which compared how people experience the game through virtual reality glasses compared to monitors. It was found that immersion increases significantly and there are various reports of feelings of nausea among users.

Another issue present in the adoption of virtual reality is the question of social isolation. In their work, [48] proposes a framework that allows users to create an experience where both the environment and the user are represented in a photo-realistic manner. Furthermore, they explore how users can communicate naturally within the simulation. Although users have reported an improvement in their social isolation, the author states that there is still much research to be done in this area.

2.4 Quality of Experience (QoE) in Virtual Reality Games

QoE in virtual reality games refers to the overall satisfaction of the player when interacting with the virtual environment. It involves aspects such as graphical performance, latency, immersion, visual realism, and response to commands. Improving QoE in virtual reality games aims to optimize these elements to provide a more engaging and satisfying experience for the user.

In [49], the authors evaluated the perceived QoE by users in relation to the same environment and varying the degree of movement freedom, that is, when the user can only simulate movement with their head and when they can also move through the scenario. According to the authors, all participants preferred the variation in which they could move around the environment. Other works that explore QoE in virtual reality games as audiovisual quality settings of simulations vary are [50], [51], [52], and [53].

In multi-user virtual environments, interaction among them can be compromised by problems in the quality of data transmission. In [54], it was studied how data latency affects the QoE of users and found values with which delay ceases to be a problem for users.

[55] study the use of edge computing services to improve QoE for mobile devices where there is a large number of users connected at the same time. To address the problem, the authors proposed an algorithm that can improve the perceived QoE by at least 18% compared to other works for VR on mobile devices. Other works aiming to improve the perception of QoE in virtual reality environments through the improvement of network data quality are [56], [57], and [58].

2.5 QoE in Serious Virtual Reality Games

Immersive training has been widely explored in areas such as construction. In many cases, this type of training requires the user to manipulate real objects while

using the simulation. This interaction can cause breaks in the user's immersion and thus negatively affect the QoE. In this context, [59] model a fiber optic installation environment with the manipulation of real objects like boxes, tables, etc., and evaluated, along with professionals from the sector, how QoE is affected with different environment settings. In some configurations, participants reported discomfort and unease. As the simulations improved some graphic configurations, users began to better accept the training without feeling unwell.

[60] highlight the growing importance of the relationship between engagement and learning outcomes in educational games, especially those based on virtual reality. Although it is proven that educational games based on virtual reality can effectively increase engagement, there are still no clear guidelines on how to design educational games to improve student engagement. Using a literature review, they propose a design model that aims to enhance efficacy and involvement in educational virtual reality games, considering Usability, Playability, and Immersion.

2.5.1 Evaluation Metrics for QoE in This Context

Typically, the evaluation of user QoE in educational virtual reality games is limited to indices of popularity, interaction praise, and attractiveness and lacks more in-depth metrics. Addressing this issue, [53] developed a framework divided into three layers: sensory layer, behavioral layer, and emotional layer, with 5 first-level indicators and 20 secondary indicators. The results indicated lower overall participant satisfaction in the sensory dimension, while scores in the behavioral and emotional dimensions were higher compared to the sensory dimension.

According to [61], the metrics used to evaluate QoE explore factors that contribute to user perception, these factors can be human factors, linked to the evaluated system, and the context of use. Since much of the QoE estimation is based on human evaluation, this measurement remains a challenging area, even for machine learning algorithms. In this manual, a standardization of metrics for machine learning algorithms for the analysis of QoE of virtual reality content is made.

2.6 Future Perspectives and Emerging Trends

One area that has been heavily explored recently is the research and development of metaverse environments. The metaverse, an interactive virtual universe that intertwines with the real world, is shaped by advanced technologies such as Virtual Reality, Augmented Reality, Mixed Reality, Artificial Intelligence, and Cloud Computing. Driven by innovations in blockchain, Artificial Intelligence, Internet of Things, and digital gaming, the metaverse is evolving rapidly. However, it faces challenges in achieving seamless integration between the real and virtual worlds. Quality of Experience (QoE) in the metaverse is profoundly impacted by the quality of content, devices, and interaction. This article focuses on recent advancements in QoE research in the metaverse, aiming to guide future studies and suggesting avenues for further investigation [62].

According to [63], other relevant open research topics in QoE include data and content security served by client-server applications, comparisons between cloud-based games and games played via emulators and mobile applications, and optimizations in high-definition and high-resolution game streaming.

2.7 RELATED WORKS

Below, research related to the theme of this work will be cited, highlighting the main ideas developed in these studies.

The study by [33] addressed the impact of the metaverse on the advancement of science and technology, emphasizing the importance of artificial intelligence (AI) in this context. The integration of AI in the sports industry is an inevitable trend, especially in transforming traditional physical education. Football teaching can benefit from Virtual Reality (VR) to create an immersive teaching process. The study proposes an optimized strategy for delivering football teaching videos in VR, using the metaverse and the K-means machine learning algorithm. Experiments show that this strategy improves response time and the quality of experience of students, allowing intuitive analysis of actions and promoting the combination of football teaching with intelligent learning.

[64] explored the successful use of Virtual Reality (VR) technologies in tourism marketing, highlighting the evolution to multisensory VR content. Investigating the impact of multisensory VR setups and user gender, the study compared gender-balanced samples in two setups (audiovisual vs. multisensory). The results indicated that spatial presence was significantly higher in the female sample in both setups, with reports of more involvement in the audiovisual condition. Correlations between spatial presence, emotions, satisfaction, involvement, enjoyment, and utility were found. Multisensory stimulation proved capable of mitigating potential gender differences in passive VR scenarios. It was concluded that VR's ability to create a physical presence in the virtual environment contributes positively

to emotions and enjoyment, influencing consumer behavior towards tourism products and services.

[65] addressed how network delays impact the experience of users of augmented reality in environments shared by users. They modeled and simulated a squash game environment and evaluated the experience of 23 squash players in a virtual reality environment, finding that a delay of 20ms in transmissions was acceptable, while 120ms was considered by the participants of the experience as completely unstable. They also compared how delays were perceived differently between men and women and according to the level of experience they had with games.

In [25], they based on pedagogical approaches for integrating technology into the learning process, offering opportunities to improve the quality of teaching and learning experiences, increasing student interest and motivation. Game-based learning, with different technologies, leverages students' energy and enthusiasm for educational purposes. To enhance the quality of the learning experience, elements of popular games (such as mobile and augmented reality games) were used in an educational context. This paper proposes a methodological guide to integrate games into education. The guide defines a two-step process for creating educational games focusing on students' attitudes and needs and then on educational outcomes. As a case study, an augmented reality educational gaming platform was designed to illustrate the benefits of the proposed approach.

In [39], a virtual environment for training professionals in the industrial sector was proposed. This project creates a realistic virtual environment that provides reliable visual operations for industrial production. The system includes technical features, such as the reproduction of the real production environment, multidimensional data input, demonstration of various processes, establishment of an interactive feedback system, and error display. This initiative aims to improve the efficiency and quality of industrial production, providing an effective solution for worker training.

In the work of [38], they developed a training environment for activities in electrical substations. The system aimed not only to provide training but also to allow real-time operation with real substations of the energy company CEMIG. During the simulation, participants used devices such as joysticks, gamepads, and virtual reality glasses to operate an electrical substation in training mode.

3 Methodology

This project aims to develop a serious training game using virtual reality (VR) technology. The game can simulate specific training scenarios, such as operating industrial equipment, medical procedures, or problem-solving skills in an immersive virtual environment. Project Steps: Development of the Serious Game: Create the VR-based serious training game, involving the creation of a 3D virtual environment, modeling relevant characters or virtual objects, and programming realistic interactions.

1. Participant Recruitment: Select professionals or students in the relevant field to participate in the study and ensure informed consent.

2. Testing and Evaluation: Ask participants to use the VR-based serious game and evaluate QoE. This can be done through questionnaires, satisfaction scales, or even physiological measurements to understand participants' reactions during virtual training.

3. Collecting Feedback: Gather qualitative feedback from participants regarding usability, realism of simulations, task difficulty, and the effectiveness of training.

4. Data Analysis: Analyze collected data to identify areas for QoE improvement, such as adjustments to the interface, interactivity, or simulation accuracy.

5. Iteration and Improvements: Based on evaluation results, make necessary improvements to the serious game to enhance QoE.

6. Repeat Evaluation: Conduct a second round of testing with a new group of participants after implementing improvements to verify whether QoE has improved.

7. Results Report: Compile study results into a report describing findings, implemented improvements, and recommendations for future iterations of the game.

This straightforward project will allow you to explore QoE evaluation in a virtual training environment using VR, with a focus on improving user experience and training effectiveness.

4 Results

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