The Timeless Chamber: A Virtual Reality Escape Room Enhancing Educational Experiences

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Abstract

"The Timeless Chamber" is a Serious Game developed in a Virtual Reality (VR) environment, aimed at supporting STEM education through immersive and experiential learning. This paper discusses the design of the game, focusing on its flexibility to accommodate different learning styles and its alignment with STEM educational objectives through gameplay mechanics. The project incorporates Conversational Artificial Intelligence to enable interactive exchanges with historical characters, which provides additional context to the learning process. The development of the game, implemented using Unreal Engine 5, highlights the technical steps taken to create a functional and immersive VR educational experience. By integrating recent technological advancements with educational frameworks, "The Timeless Chamber" aims to serve as a supportive tool in STEM education, exploring the potential benefits of Virtual Reality and Artificial Intelligence in creating an engaging learning environment.

Keywords: *Virtual Reality, Serious Games, Cultural Heritage, Unreal Engine, Conversational Artificial Intelligence.*

1. Introduction

The Virtual Reality (VR) gaming industry is experiencing steady growth. Market data indicates that, in 2022, the global VR gaming market was valued at approximately $20.73 billion. Furthermore, it is projected to grow at a Compound Annual Growth Rate (CAGR) of 22.7% from 2023 to 2030 [1]. VR enables users to explore, alter, and interact with complex data through computer technology. It generates sensory experiences, such as visual and auditory feedback, to recreate a digital environment [2]. VR transcends the mere creation of lifelike settings; it engineers immersive, synthetic universes that adapt to user interactions, whether through speech, commands, or movements. This capability to dynamically respond in real-time encapsulates the core principle of Virtual Reality, offering a profound level of engagement and interactivity [3]. At the heart of VR is the genuineness of its experiences: the extent to which a video game replicates reality directly influences the depth of player immersion [4].

The rising availability of Head-Mounted Displays (HMDs) has inspired software developers to explore innovative methods for crafting immersive experiences, extending into the educational domain as well [5]. A significant challenge identified in the contemporary educational system is the diminished motivation and engagement of students with the curriculum [6]. Serious Games in Virtual Reality present an alternative approach to learning and training. Highly immersive VR experiences have been designed to teach various subjects, yielding tangible outcomes [7].

Serious Games prioritize education over entertainment, representing the most common form of Game-Based Learning (GBL) in education [8]. They aim to achieve specific educational objectives, enhancing enthusiasm for learning and academic performance [9]. Applications extend to fields like scientific simulation, military training, medical education, and public awareness [10]. By integrating game mechanics, storytelling, and reward systems, Serious Games support learning, skill development, and progress assessment. Studies confirm their effectiveness in boosting cognitive and emotional skills, as well as improving information retention and transfer [11].

The use of immersive virtual reality (IVR) in education, especially in higher education, has gained significant attention in recent years [12]. IVR enhances the learning experience by providing engaging, interactive, and authentic environments that encourage active student participation [13]. It serves as a powerful tool for simulating real-world scenarios, helping students grasp complex concepts through hands-on experiences [14]. Additionally, head-mounted displays (HMDs) have been shown to effectively improve learning outcomes by delivering deeply immersive experiences [15].

Research highlights the application of IVR across diverse educational fields [16]. In legal education, IVR has been used to create virtual courtrooms where students develop public speaking and legal argumentation skills by interacting with avatars [17]. In teacher training, it simulates classroom environments, enabling future educators to practice managing classroom dynamics and student behavior. Key advantages of IVR in education include the ability to simulate dangerous or inaccessible environments, providing safe opportunities to develop and refine skills. For instance, IVR is employed in clinical psychology and social work to replicate challenging scenarios like client interactions or crisis interventions. Additionally, its use in virtual tours of historical sites and museums supports cross-cultural education, allowing students to explore and compare cultures in a deeply immersive way.
While immersive virtual reality (IVR) presents significant educational opportunities, its adoption faces notable challenges. Reported issues include physical discomforts like nausea and dizziness, technical limitations related to device quality and resolution, and the high cost of VR equipment, which hinders widespread use in educational institutions. The effectiveness of IVR relies heavily on its seamless integration with learning objectives, as unclear educational value or difficult-to-use technology can reduce student engagement [17]. Additionally, many current applications remain experimental and not fully optimized for education. Despite these hurdles, the potential of IVR as a transformative tool for immersive, interactive learning is evident, highlighting the need for further research and development to overcome these barriers and establish effective practices for its implementation.

2. Unreal Engine 5 for VR development

Unreal Engine 5 (UE5) represents a major advancement in VR development, offering groundbreaking real-time rendering and specialized tools for creating immersive VR experiences. However, developing VR with UE5 requires meticulous optimization to achieve responsive and engaging environments. Key considerations include the use of technologies like static lighting, Nanite, and selecting between deferred and forward shading, all while maintaining a minimum frame rate of 70 fps to ensure smooth and immersive gameplay.
Recent researches [18] delve into the nuances of optimizing VR environments, particularly focusing on vegetation rendering in Unreal Engine. They demonstrates that employing optimization techniques such as Levels of Detail (LOD) and culling algorithms can significantly enhance rendering efficiency. For instance, LOD techniques dynamically adjust the complexity of 3D models based on their distance from the user, thus reducing the processing load without compromising visual quality. This is especially relevant in lush or densely vegetated VR scenes where rendering detailed foliage at a distance is unnecessary and computationally taxing. Additionally, the implementation of culling algorithms, which selectively render only those objects visible to the user, further streamlines the rendering process. By optimizing the rendering of vegetation and other complex geometries, VR developers can maintain the immersive quality of their environments while ensuring stable and high frame rates, crucial for a seamless VR experience.
In VR development using Unreal Engine 5 (UE5), the use of static or baked lighting plays a crucial role. Contrary to dynamic lighting, static lighting undergoes precomputation and is stored within lightmaps, markedly reducing the computational burden in real-time. This factor is particularly vital in VR contexts, where sustaining a high and consistent frame rate is imperative to avoid motion sickness and guarantee a seamless, immersive experience. Recent studies [19] sheds light on the utility of static environments in Unreal Engine game development, focusing on AI pathfinding. However, the principles they present regarding optimization in a gaming engine are applicable here. They highlight the benefits of static components in diminishing computational requirements, which, in the case of VR, translates to the need for static lighting to ensure smooth operation without excessive system strain. By embedding lighting into scenes, developers can craft aesthetically pleasing and realistic environments without sacrificing performance. Thus, employing Unreal Engine 5's capabilities for static lighting emerges as a strategic decision for VR developers striving to balance visual quality with system efficiency.
Nanite, a pivotal feature of Unreal Engine 5, significantly bolsters the development and portrayal of intricate virtual environments, proving exceptionally beneficial for VR applications. A recent case study exemplifies Nanite's impact in enhancing the visualization of complex 3D models, particularly in applications like virtual museums and interactive displays. In this context, current findings [20] analyzed the performance of photogrammetric models, comparing those optimized with traditional remeshing techniques against those utilizing Nanite. Nanite's use streamlined the workflow by obviating the need for manual mesh and texture edits. This efficiency in time and expertise, with the direct conversion of photogrammetric models into Nanite objects, is invaluable in visualizing extensive collections of heritage items or intricate scenes in virtual settings, ensuring detailed high-quality renditions without compromising performance. For VR development, Nanite's proficiency in managing

vast geometric details is essential. It facilitates the creation of more realistic and immersive environments without burdening the VR system, leading to a smoother and more responsive user experience. Nanite's effectiveness in rendering complex geometries while maintaining optimal performance is well-suited to the requirements of VR, where sustaining a high frame rate is critical for user comfort and immersion. Furthermore, choosing between deferred and forward shading in Unreal Engine 5 for VR experiences is a crucial decision that can significantly influence both the performance and visual quality of the virtual environment. Deferred shading is typically preferred in scenarios with numerous light sources, enabling more efficient rendering of complex lighting situations. In deferred shading, rendering is divided into two stages: the first stage gathers data about scene pixels (e.g., position, color, normal), and the second calculates lighting. This method is more capable of handling a large number of lights than forward shading but demands greater memory and computational resources, a key consideration in VR for maintaining high frame rates. Forward shading, conversely, computes the lighting of objects in a single pass as the scene renders. This approach is often more memory-efficient and supports superior anti-aliasing techniques, crucial for VR's visual quality. Forward shading is generally employed in scenarios with fewer light sources or when hardware capabilities are limited.

In the landscape of VR development leveraging Unreal Engine 5, the integration of Deep Learning Super Sampling (DLSS) by Nvidia emerges as a pivotal strategy for augmenting performance. DLSS employs artificial intelligence and machine learning to upscale images in real-time, allowing for lower native resolutions without compromising visual fidelity [21]. This technology is particularly advantageous in VR environments where maintaining high frame rates is not just desirable for quality, but essential for user comfort. The utility of DLSS in VR is underscored by its ability to render complex scenes at lower resolutions, which are then intelligently upscaled to higher resolutions. This process significantly reduces the computational load on graphics processors, enabling them to maintain higher frame rates even in graphically intensive scenarios. In a VR setting, where the demand for high-resolution imagery is balanced with the need for fluid motion and responsiveness, DLSS offers a harmonious solution. It enhances the overall experience by providing crisp, clear images, crucial for immersion and realism in VR, while ensuring that the performance remains consistent and reliable. Moreover, DLSS's adaptive nature means that it can scale performance according to the hardware's capabilities. This flexibility is particularly beneficial in the diverse ecosystem of VR hardware, where users may have varying levels of system power. By adjusting the balance between image quality and performance based on the hardware's capabilities, DLSS ensures a smooth VR experience across a wide range of devices.

3. The Timeless Chamber

Fig. 1. "The Timeless Chamber"

"The Timeless Chamber" is an immersive VR escape room experience designed to engage teenagers and adults in learning subjects such as STEM, history, and art. Escape Rooms are engaging games requiring players to solve puzzles and tasks quickly. The primary objective often involves exiting a specific room, location, or setting. When these experiences serve an educational function, they are typically referred to as Educational Escape Rooms. They effectively boost student motivation and engagement through gamification and Game-Based Learning principles [22]. The game incorporates

the traditional dynamics of physical escape rooms, transitioning them into a virtual environment to facilitate global student accessibility, thus overcoming geographical and logistical hurdles.
The game was developed and optimized using Unreal Engine 5 and has been tested on the Meta Quest 2. The design of our game is founded on the MDA framework [23], which is structured around three key elements: Mechanics, Dynamics, and Aesthetics. Mechanics encompass the game's individual components and algorithms. Dynamics detail the interaction and behavior of these mechanics during gameplay. Aesthetics aim at invoking specific emotional reactions from players as they interact with the game.
In "*The Timeless Chamber*", players navigate through various thematic rooms, each anchored by a specific character who guides them through the game experience. These characters represent real historical figures whose actions, discoveries, or creations have etched their names into the annals of history. The goal is to facilitate direct interaction between players and the characters they have traditionally encountered in textbooks, by bringing them together in a specially designed virtual world for an immersive experience. Historical figures are physically present in each room, allowing players to interact naturally with them for clues to solve puzzles, uncover secrets, and successfully complete the level. Interactions with historical figures are facilitated via natural language, offering players clues to progress within the narrative as well as providing historical and contextual background that leads them towards unraveling the presented puzzles. By giving tips on how objects should be positioned in the room and sharing tales from their lives, these characters serve as mentors. They are benevolent entities in each level, aiding and steering players through their developmental journey [24]. This development is conceived not merely in the context of advancing through the game's levels, but also in personal growth, marked by the lasting assimilation of significant knowledge [25].
The objective, akin to traditional escape rooms, is to escape by solving puzzles before time expires. Players are required to meticulously inspect the room, finding necessary objects to solve an array of quests, progressively inching closer to solving the overarching mystery. Solving puzzles not only advances players towards victory but also enriches them with extensive information on the room's dedicated theme. The game's title echoes its foundational game design elements: the assortment of rooms plunges players into a temporal voyage, allowing them to collect insights from figures who have defined historical eras or whose discoveries and masterpieces have achieved timelessness.
Every facet of the game is designed to give players the sensation of being transported into the historical era featured in each level. As the game traverses various epochs, every room and its quests are meticulously themed to align with the subject matter of the level and the historical figure it portrays. The visual style integrates elements that capture the essence of the different historical periods and themes explored. Likewise, the game's soundtrack is tailored to each era, augmenting the authenticity of interactions with historical characters, thereby enriching the immersive experience.
The level of challenge in the game is progressive, indicated at each room's entrance. Players have the autonomy to select their challenge, whether it's based on a preferred subject, a historical figure they aim to encounter, a specific topic of interest, or the puzzle difficulty within the escape room. The capacity for players to make diverse and consequential choices is vital for a video game's success, as the liberty of choice needs to be integrated with a system where these choices significantly impact the gaming experience. Enabling learners to choose their educational path and evaluate the outcomes of their selections renders the educational journey more impactful and potentially more rewarding [26]. Players will not feel obliged to tackle levels too simplistic for their abilities or misaligned with their learning goals. Offering players this freedom aims to engage them in a state of flow, ensuring they are fully immersed and undistracted, enhancing their satisfaction with the activity [27].
Primarily crafted for online multiplayer gameplay, the game promotes worldwide collaboration, urging players to engage in collective learning with individuals from diverse geographical, linguistic, and cultural contexts, all driven by a shared pursuit of knowledge enrichment. It accommodates up to four players in each game and offers a single-player mode with computer-controlled characters for a versatile gaming experience. During this initial experimental phase, the game will also support private game lobbies, enabling players to face challenges alongside their friends or classmates. This approach aims not only to provide the option of playing with familiar companions but also to polish the product by reducing the likelihood of critical bugs before its online release.
In the game world, interaction is enhanced by the use of VR controller teleportation or actual physical movement, giving players the freedom to navigate and interact with their surroundings. This immersive environment is filled with a plethora of objects for players to discover and manipulate, encouraging them to experiment and solve diverse puzzles through a process of trial and error. Additionally, players are given the choice to focus on specific macro-topics, with each room categorized by its level of difficulty and associated with a narrating historical figure, enriching the educational experience.

Fig. 2. Example of escape room puzzle.

Levels must be completed within a time limit ranging from fifteen to thirty minutes, depending on the level's difficulty. Virtual Reality is optimally utilized to immerse players in any setting imaginable, from artistic studios to war scenario recreations. The puzzles demand interdisciplinary knowledge, leveraging the collective intellect of the team for obstacle navigation through critical thinking and collaboration. Furthermore, the puzzles are educational at their core, blending the fun aspect evident from historical characters' interactions with players, integrating historical facts, artistic explanations, and various contexts to transform each puzzle into a learning opportunity. Nevertheless, while maintaining the essence of a playful setting, characters will combine their genuine stories with fictional narrative devices. These are designed to lead players through engaging and frequently surreal adventures, with the objective of revealing new clues for game progression.
The design aims to cater to all player types identified in Bartle's taxonomy. The game includes leaderboards for each room, documenting the highest achievements by player teams globally. This competitive aspect encourages players to pursue top scores, appealing particularly to the so-called ``Killers''. Its cooperative aspect meets the needs of socializers by fostering connections with a variety of individuals. Explorers will appreciate uncovering hidden objects or those that act as puzzle elements. Meanwhile, achievers are enticed with the chance to unlock thematic achievements by accomplishing specific game goals, such as completing a series of rooms related to a character or achieving a certain score.

4. Pythagoras's Demo Level

As part of the project, a demo level was developed where players face challenges within the *"Timeless Chamber"*, designed and inspired by the teachings of the philosopher and mathematician Pythagoras. These challenges, designed for a teenage audience, aim to teach the “Pythagorean Theorem”, which states that *“if a right triangle has sides of lengths a, b, and c, with c being the hypotenuse (the side opposite the right angle), then* $a^2 + b^2 = c^2$*"* [28]. This is achieved through a series of minigames that encourage collaboration among players to overcome obstacles within a 15-minute limit.
The adventure begins in an ancient room, filled with mathematical symbols and instruments that create an atmosphere of ancient wisdom. Upon entering, players encounter an animated version of Pythagoras, rendered as a talking statue and brought to life through sophisticated artificial intelligence technologies. Pythagoras introduces himself and the predicament he faces: a mysterious object has struck him on the head, causing him to forget his latest mathematical discovery, the famous theorem that bears his name. This setup not only establishes the educational game's tone but also presents the central challenge. Players are thus engaged in a mission to help Pythagoras recover his lost memory by solving a series of puzzles that emphasize geometry and mathematical reasoning. This interactive narrative framework invites players to delve into the world of ancient mathematics, blending historical intrigue with educational objectives.

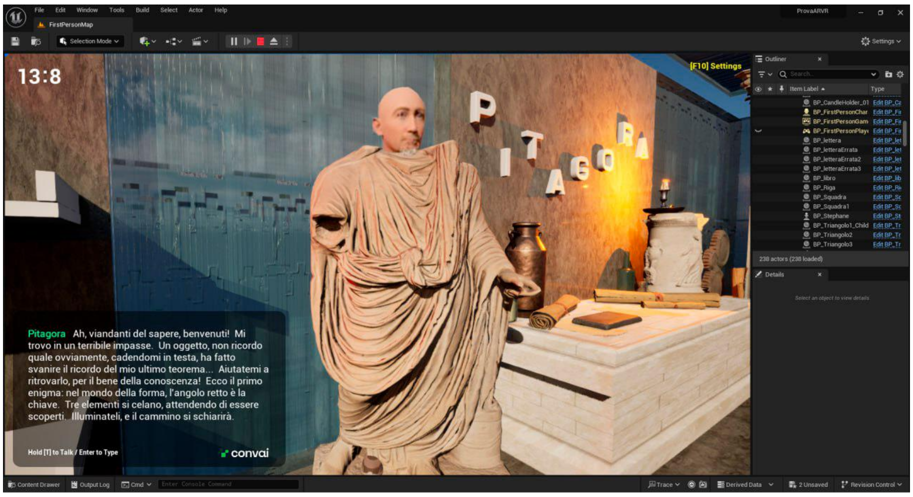

Fig. 3. Pythagoras's First Encounter

Despite his confusion from the accident, Pythagoras manages to offer a starting clue for the game. He suggests that in the realm of geometric shapes, the right angle is crucial. He hints that three hidden elements are essential to progress, and these need to be discovered by the players. This clue sets the players on their initial quest, guiding them to focus on finding and understanding the significance of right angles within the various shapes they encounter throughout the game. Players must explore the chamber to find right triangles, which are central to reconstructing the forgotten theorem. As they navigate the room, either by walking or using teleportation, they can interact with various elements to solve the puzzle.

In this demo level, players are engaged through a series of educational mini-games designed to teach and reinforce the principles of Pythagoras' theorem within a virtual reality environment. These games range from identifying hidden right triangles among various geometric shapes to assembling puzzles that form right triangles, each enhancing understanding of geometric relationships. Players also embark on quests to find specific books containing the theorem's formula, apply their knowledge to measure triangle sides, and ultimately calculate the hypotenuse. Each game is crafted to challenge the players' problem-solving and observational skills while making the learning experience interactive and enjoyable. Through these diverse activities, the game effectively combines education with engaging gameplay, enhancing both understanding and retention of mathematical concepts.

Each mini-game within *"The Timeless Chamber"* is meticulously crafted to ensure that players not only learn mathematical concepts but also enjoy the process, making education an immersive experience. The mini-games culminate with the players successfully solving the final problem, aiding Pythagoras in regaining his lost memory. Pythagoras congratulates the players, reinforcing the value of learning and the joy of mathematical discovery.

In the evolving domain of educational VR games, the incorporation of AI-powered Non-Player Characters (NPCs) notably enhances the learning environment by simulating dynamic and interactive experiences akin to human interactions. A prime example of this technological application is evident in *"The Timeless Chamber"*, where the ConvAI framework [29] integrated into Unreal Engine facilitates the development of NPCs that can engage in sophisticated conversations. An animated version of the historical figure Pythagoras is utilized to exemplify this, interacting with players in real-time to guide them through educational puzzles based on the Pythagorean Theorem, thereby personalizing the learning trajectory.

The technical integration of ConvAI into Unreal Engine is streamlined and involves several key steps, starting with the activation of the ConvAI plugin [30], configuration of API keys, and the detailed setup of character traits that align with the game's educational goals. This base knowledge for NPCs like Pythagoras is manually defined within the ConvAI system to ensure alignment with the educational content of *"The Timeless Chamber"*. Once this foundational knowledge is established, the system leverages Nvidia Avatar Cloud Engine (ACE) [31] to enhance the NPCs' ability to engage in dynamic interactions. This setup allows the AI to adapt its responses based on real-time player interactions and feedback, creating a more personalized and interactive learning environment.

Additionally, the MetaHuman plugin [32] is utilized to provide NPCs with highly realistic human appearances, thereby enhancing the VR experience's immersion and authenticity. The combination of manually defined knowledge and Nvidia-powered dynamic interactions, specifically through the use of Nvidia Riva's text-to-speech and speech-to-text models from the ACE framework, ensures that the AI-

driven NPCs can offer customized feedback and motivation. These models enable the NPCs to adjust their instructional pace and complexity to meet the individual needs of learners. This sophisticated dialogue system is designed to replicate a human tutor's adaptability and responsiveness, making the educational process both engaging and effective.
Moreover, these NPCs play a pivotal role in transforming passive learning into an active, engaging process. Through interactive problem-solving and personalized engagement, they help maintain a compelling educational environment that is responsive to individual learning preferences and performance. The use of AI to animate characters like Pythagoras not only makes historical figures relatable and accessible but also significantly deepens the educational experience by integrating responsive and interactive elements that traditional educational methods often lack.
This innovative use of generative AI in VR educational games represents a transformative advancement in educational technology, merging engagement, personalization, and immersive learning to foster a deeper understanding and retention of educational content. By effectively blending advanced AI interactions with carefully crafted educational narratives and challenges, *"The Timeless Chamber"* showcases the potential of VR to revolutionize educational methodologies.

5. Conclusion

“The Timeless Chamber” exemplifies how virtual reality technology can be used to revolutionize traditional learning methodologies. By integrating gameplay mechanics, interactive feedback, and advanced technological platforms, this game not only facilitates the learning of numerous themes but also fosters deep and enduring understanding through active engagement and interaction. Future research should focus on incorporating real-time user feedback to further refine the educational experience. Additionally, subsequent iterations of the game could explore the use of emerging technologies such as Nvidia's Deep Learning Super Sampling (DLSS), which could significantly enhance visual performance while maintaining high frame rates crucial for an immersive and comfortable VR experience.
Further development could involve expanding the range of themes and contexts addressed in the game, utilizing Unreal Engine 5 to create even more realistic and engaging settings. This would not only make the game more appealing to a broader audience but could also improve students' abilities to retain complex information and apply it across various contexts. Moreover, the exploration of integrating conversational AI algorithms to generate more natural and realistic Non-Player Characters (NPCs) could greatly enrich user interaction and engagement, making learning a more profound and intuitive experience.
This advanced application of VR in education demonstrates potential pathways for significant enhancements in educational outcomes. As VR technology continues to evolve, its integration into educational settings offers promising prospects for creating more dynamic and interactive learning environments. These advancements could lead to a paradigm shift in how educational content is delivered, moving away from traditional didactic methods to more experiential and engaging forms of learning.

REFERENCES

[1] Grand View Research Virtual Reality In Gaming Market Size & Share Report, 2030 — Grandviewresearch.Com 2023.
[2] Isdale, J. What Is Virtual Reality. Virtual Reality Information Resources http://www. isx. com/∼ jisdale/WhatIsVr. html 1998, 4.
[3] Burdea, G.C.; Coiffet, P. Virtual Reality Technology; John Wiley & Sons, 2003;
[4] Buttussi, F.; Chittaro, L. Effects of Different Types of Virtual Reality Display on Presence and Learning in a Safety Training Scenario. IEEE transactions on visualization and computer graphics 2017, 24, 1063–1076.
[5] Vercelli, G.V.; Iacono, S.; Vallarino, M.; Zolezzi, D. Puzzle Battle 2.0: A Revisited Serious Game in VR During Pandemic’s Period. In Proceedings of the Games and Learning Alliance: 10th International Conference, GALA 2021, La Spezia, Italy, December 1–2, 2021, Proceedings 10; Springer, 2021; pp. 252–257.
[6] Zichermann, G.; Cunningham, C. Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps; O’Reilly Media, Inc., 2011;
[7] Checa, D.; Bustillo, A. A Review of Immersive Virtual Reality Serious Games to Enhance Learning and Training. Multimedia Tools and Applications 2020, 79, 5501–5527.

[8] Michael, D.R.; Chen, S. Serious Games: Games That Educate, Train and Inform; Thomson Course Technology, 2006; ISBN 978-1-59200-622-9.
[9] Dahalan, F.; Alias, N.; Shaharom, M.S.N. Gamification and Game Based Learning for Vocational Education and Training: A Systematic Literature Review. Education and Information Technologies 2024, 29, 1279–1317.
[10] Barnes, T.; Encarnação, L.M.; Shaw, C.D. Serious Games. IEEE Computer Graphics and Applications 2009, 29, 18–19.
[11] Yücel, F.; Ünal, H.S.; Surer, E.; Huvaj, N. A Modular Serious Game Development Framework for Virtual Laboratory Courses. IEEE Transactions on Learning Technologies 2024.
[12] Rogers, S.L.; Hollett, R.; Li, Y.R.; Speelman, C.P. An Evaluation of Virtual Reality Role-Play Experiences for Helping-Profession Courses. Teaching of Psychology 2022, 49, 78–84.
[13] Shadiev, R.; Wang, X.; Huang, Y.-M. Cross-Cultural Learning in Virtual Reality Environment: Facilitating Cross-Cultural Understanding, Trait Emotional Intelligence, and Sense of Presence. Educational Technology Research and Development 2021, 69, 2917–2936.
[14] Makransky, G.; Lilleholt, L. A Structural Equation Modeling Investigation of the Emotional Value of Immersive Virtual Reality in Education. Educational Technology Research and Development 2018, 66, 1141–1164.
[15] Wu, B.; Yu, X.; Gu, X. Effectiveness of Immersive Virtual Reality Using Head-Mounted Displays on Learning Performance: A Meta-Analysis. British journal of educational technology 2020, 51, 1991–2005.
[16] Radianti, J.; Majchrzak, T.A.; Fromm, J.; Wohlgenannt, I. A Systematic Review of Immersive Virtual Reality Applications for Higher Education: Design Elements, Lessons Learned, and Research Agenda. Computers & education 2020, 147, 103778.
[17] McFaul, H.; FitzGerald, E. A Realist Evaluation of Student Use of a Virtual Reality Smartphone Application in Undergraduate Legal Education. British Journal of Educational Technology 2020, 51, 572–589.
[18] Zhang, Z.; Luo, X.; Salazar Vaca, M.G.; Espinoza Castro, D.A.; Chen, Y. Vegetation Rendering Optimization for Virtual Reality Systems. In Proceedings of the 2017 International Conference on Virtual Reality and Visualization (ICVRV); 2017; pp. 397–399.
[19] Xie, Y.; Chen, Y.; Wang, Z.; Ou, Y. AI Intelligent Wayfinding Based on Unreal Engine 4 Static Map. Journal of Physics: Conference Series 2022, 2253, 012016, doi:10.1088/1742-6596/2253/1/012016.
[20] Díaz-Alemán, M.D.; Amador-García, E.M.; Díaz-González, E.; de la Torre-Cantero, J. Nanite as a Disruptive Technology for the Interactive Visualisation of Cultural Heritage 3D Models: A Case Study. Heritage 2023, 6, 5607–5618, doi:10.3390/heritage6080295.
[21] Tecnologia NVIDIA DLSS. NVIDIA, https://www.nvidia.com/it-it/geforce/technologies/dlss/
[22] Grande-de-Prado, M.; García-Martín, S.; Baelo, R.; Abella-García, V. Edu-Escape Rooms. Encyclopedia 2020, 1, 12–19.
[23] Hunicke, R.; LeBlanc, M.; Zubek, R.; others MDA: A Formal Approach to Game Design and Game Research. In Proceedings of the Proceedings of the AAAI Workshop on Challenges in Game AI; San Jose, CA, 2004; Vol. 4, p. 1722.
[24] Vogler, C. The Writer's Journey: Mythic Structures for Screenwriters and Storytellers; M. Wiese Productions, Studio City, CA, 1992; ISBN 978-0-941188-13-5.
[25] Youssef, Y. Gamification in E-Learning. 2015.
[26] Sezgin, S.; Bozkurt, A.; YILMAZ, E.A.; Van Der Linden, N. Oyunlaştırma, Eğitim ve Kuramsal Yaklaşımlar: Öğrenme Süreçlerinde Motivasyon, Adanmışlık ve Sürdürebilirlik. Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi 2018, 169–189.
[27] Csikszentmihalyi, M. Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi; Springer Netherlands, 2014; ISBN 978-94-017-9088-8.
[28] Cagol, M.; Colombi, A.E. Pythagoras on the Rocks. A Proof with Bricks. Form@ re-Open Journal per la formazione in rete 2016, 16, 268–274.
[29] Convai - Conversational AI for Virtual Worlds, https://convai.com/, https://www.convai.com/
[30] Unreal Engine - Documentation 2024, https://docs.convai.com/api-docs/plugins-and-integrations/unreal-engine
[31] Spotlight: Convai Reinvents Non-Playable Character Interactions. NVIDIA Technical Blog 2024.
[32] MetaHuman - Realistic Person Creator. Unreal Engine, https://www.unrealengine.com/en-US/metahuman