From Past to Present

A study of AI-driven gamification in heritage education

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The use of Artificial Intelligence (AI) in educational gamification marks a significant advancement, transforming traditional learning methods by offering interactive, adaptive, and personalized content. This approach makes historical content more relatable and promotes active learning and exploration. This research presents an innovative approach to heritage education, combining AI and gamification, explicitly targeting the Silk Roads. It represents a significant progression in a series of research, transitioning from basic 2D textual interactions to a 3D environment using photogrammetry, combining historical authenticity and immersive gameplay. It features AI-driven characters developed in Unreal Engine, which provides heritage insights augmented by personalized interactions, highlighting the importance of collaborative tools like interactive quizzes for enriching education and promoting critical thinking and community among learners. In conclusion, this research underlines the transformative impact of AI and gamification in heritage education enhancement, integrating real-time voice conversation and interactive pedagogical methods into immersive 3D environments as a supplementary tool.

Keywords: *Heritage Education, Gamification, Artificial Intelligence, Unreal Engine.*

INTRODUCTION

The Silk Roads, an ancient network of trade routes connecting the East and West, played a pivotal role in facilitating the exchange of goods, and cultural, religious, and intellectual interactions (Zhang et al, 2015). These routes influenced the geography of Asia's highland regions and the transmission of diseases like the plague in pre-industrial Europe (Yue, Lee, and Wu, 2017). As a prominent trade link, the Silk Roads enabled the exchange of items such as silk, cotton cloth, and tea (Yuan and Schmerer, 2017). They also facilitated the transmission of cultural products along the Maritime Silk Roads (Li et al, 2019; Tian et al, 2015) and affected the genetic composition of populations and the resilience of human-water systems in regions like the Southern Silk Roads (Tian et al, 2015; Xu et al, 2019). Integral to the Silk Roads' rich history were the caravanserais, which provided a glimpse into the past by facilitating cultural exchange and trade far beyond their basic function as rest stops (Deljavan and Çinar, 2023). These caravanserais were hubs of exchange and innovation, influencing urban planning and landscape in Central Asia (Volichenko and Huang, 2023) and serving strategic purposes like defense during the Seljuk Empire (Özcan, 2010). The sustainable adaptation of Safavid caravanserais in Iran highlights their relevance in contemporary development (Saberi et al, 2016), and their architectural impact is evident in cities like Bukhara

(Abdullaev, 2021). Their central role in historical and archaeological landscapes is also recognized in studies of agricultural micro-districts and medieval villages (Vorderstrasse, and Բարայան, 2017).

The importance of the Silk Roads and the caravanserais located on it in historical trade and cultural exchange is undeniable, and in an era increasingly shaped by digital technology, there is a compelling need to digitize and preserve this legacy (Mansourihanis et al, 2023). This initiative began with a digital heritage course project that mapped and documented caravanserais along the Silk Roads, creating a comprehensive GIS database. In its different phases, this project not only preserved crucial historical data but also incorporated gamification elements to enhance the learning experience. Building upon this foundation, the current research advances significantly by employing Unreal Engine and Artificial Intelligence (AI) to create a more immersive educational experience. This study investigates how integrating AI and gamification in Unreal Engine can heighten student engagement and learning effectiveness in heritage education. The guiding research question is: 'How can integrating AI and gamification within a virtual environment, particularly using Unreal Engine technology, enhance student engagement and learning effectiveness in heritage education?' This endeavor strives to transform heritage education, merging the advanced capabilities of AI with the immersive qualities of professional game development software, potentially revolutionizing how we interact with and understand history.

LITERATURE REVIEW

Gamification, initially conceptualized to apply game mechanics in non-game settings, enhances online appeal and user experience (Terrill, 2008). This idea was expanded to include the integration of game design elements into everyday activities (Deterding et al, 2011) and later to create game-like experiences for service enhancement and user value (Huotari and Hamari, 2012). The significance of this approach in service marketing and transforming activities to resemble games, linking academic theory with practical application, was highlighted (Werbach, 2014). The primary aim of gamification is to boost user motivation, influence behaviors, and lead to psychological effects and behavioral changes (Blohm and Leimeister, 2013). The motivational impact of gamification elements, especially badges, is discussed (Hamari, Koivisto, and Sarsa, 2014), emphasizing their role in encouraging desired behaviors (Hamari and Eranti, 2011). However, it is noted that gamification's essence extends beyond mere points and badges, suggesting a broader application (Werbach, 2014). Gamification's application has been widely adopted across numerous sectors, showing its versatility and effectiveness in fields like commerce (Hamari, Koivisto, and Sarsa, 2014), business and marketing (Hamari and Eranti, 2011), logistics (Kumar, 2013), and notably in education (Hamari and Koivisto, 2013). Its impact on education, while varied in terms of student engagement and learning effectiveness, highlights its potential to captivate learners and enhance educational experiences (Aini, 2019). This showcases gamification's adaptability and success in diverse scenarios.

Building on this foundation of gamification in education, we now turn our attention to the evolving role of AI in this domain. Considering the notable attention AI has gained recently in games and gamification, especially in educational contexts, this field is full of innovation, and the development of player behavior models, the procedural generation of new content, and the creation of believable game agents are areas of active research (Suresh and Dhakshina, 2024). AI has been implemented in various commercial computer games and academic research, focusing on improving games' intelligence and attraction (Cavazza, 2000; Hou et al, 2009). Overall, the integration of AI in games and gamification has the potential to revolutionize educational experiences, but it also presents challenges that require further exploration and refinement.

In the context of heritage, the integration of AI in games and gamification has the potential to revolutionize the preservation and dissemination of cultural heritage. AI technologies can be utilized to develop interactive and immersive educational games that engage learners in exploring and understanding different aspects of cultural heritage. By incorporating AI-driven game elements, such as personalized learning paths and adaptive feedback, educational games can be tailored to learners' individual needs and preferences, thereby enhancing their overall learning experience (Bezzina, Pfeiffer, and Dingli, 2021). Furthermore, the application of AI in heritage-based gamification can facilitate the creation of virtual environments that simulate historical settings, allowing users to interact with and experience cultural heritage in a dynamic and engaging manner (Hamieh, 2021). This approach aligns with the shift towards personalized and experiential learning, which is particularly relevant in the context of heritage education (Arsarkij and Laohajaratsang, 2021).

Moreover, AI technologies can contribute to the development of intelligent tutoring systems within heritage-based gamification, providing learners with personalized guidance and support as they engage with cultural heritage content. These systems can utilize AI algorithms to analyze learners' interactions and performance within the game, subsequently offering tailored recommendations and scaffolding to enhance their understanding of heritage concepts (Popenici and Kerr, 2017). Additionally, the use of AI in heritage gamification aligns with the broader trend of AI-enabled personalized education, which aims to provide adaptive and individualized learning experiences to learners across various domains, including heritage education (Crompton and Song, 2021). As AI continues to advance, its integration into heritage-based gamification holds considerable promise for preserving and promoting cultural heritage, offering innovative and engaging educational experiences that cater to diverse learner needs and preferences. However, despite the educational advantages offered by AI, Yu and Wang

(2024) highlight related concerns such as privacy, academic integrity, and misinformation. Addressing these issues necessitates regulatory oversight and ethical standards.

RESEARCH BACKGROUND AND EVOLUTION

This study is the latest in our series of progressive phases exploring the cultural heritage of the Silk Roads through gamification, each phase building upon the previous to enhance the depth and engagement of the educational experience. The journey commenced with the development of text-based interactive games using the Twine platform, initially focusing on caravanserais in Iran (Eshaghi et al, 2021) before being extended to those in Turkey (Vaez Afshar et al, 2021). These early stages combined rich narratives of the Silk Road with GIS data, aiming to immerse players in historical narratives through interactive storytelling (Eshaghi et al, 2023). The project then evolved, transitioning from 2D text-based interactions to 3D virtual tours, integrating 360-degree images and VR technologies to create more immersive player experiences (Varinlioglu et al, 2022). The project also ventured into transforming GIS data into a board game, later augmented during a workshop titled bo[AR]d GAME (2022), with advanced elements like photogrammetry and 2D and 3D character designs to further enhance player engagement.

Named *SILK*, the current phase of the research represents a major advancement through a collaborative effort among prestigious universities. It involves the use of comprehensive, detailed scans using drones and photogrammetry scanners to create 3D models of historic sites like the Incir Han Caravanserai in Turkey (Varinlioglu, 2023). Constructed in 1339 and now in ruins, Incir Han provides a unique window into the past, offering a rich opportunity for exploration and gamification. This phase of the study explores the implementation of an AI-guided gamified virtual experience within the Unreal Engine infrastructure. By utilizing the

photogrammetry model of Incir Han, the project aims to create a highly realistic and immersive educational experience, bringing the historical site to life with interactive 3D environments. Although currently in its prototype stage, this phase sets a crucial foundation for future development. It serves as a proof of concept, demonstrating the feasibility and potential impact of integrating gamification and AI in heritage education. This initial yet pivotal phase sets the stage for more improvements, thorough testing, and detailed evaluations, guiding the future direction of this new educational method.

DEVELOPMENT PROCESS

Creating a gamified immersive virtual caravanserai in Unreal Engine

Unreal Engine 5.2 (2024) stands at the forefront of game development technology, offering tools for creating immersive and interactive 3D environments. Its advanced rendering capabilities, realistic physics simulations, and comprehensive suite of design tools make it an ideal platform for developing an educational and engaging virtual experience of a historic caravanserai. This part encompasses the step-by-step process of bringing the caravanserai to life within this powerful engine.

Importing the photogrammetry model.

The first step involves importing the detailed photogrammetry model of the caravanserai into Unreal Engine. This process starts by converting the model into a compatible format, typically FBX or OBJ, ensuring that it retains its intricate details while being optimized for performance in MeshLab software. Adjustments such as reducing the polygon count and texture mapping are crucial to maintain a balance between visual fidelity and engine efficiency.

Integrating dynamic environmental elements, animations, and audio.
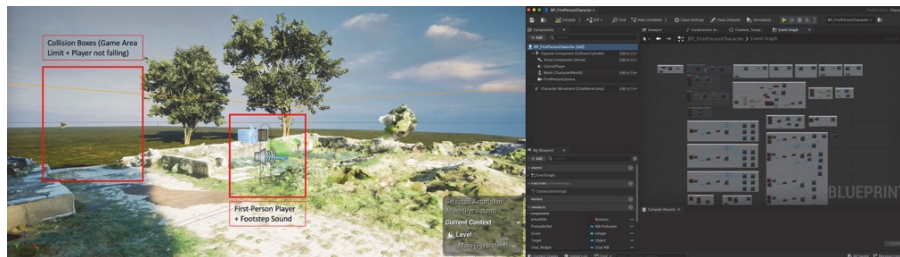
After importing a photogrammetry model of the Incir Han Caravanserai into Unreal Engine, the project focuses on enhancing realism and immersion by integrating dynamic environmental elements, animations, and audio (Rohani and Kim, 2023). This includes adding lighting, landscape, and auditory components to mirror the historic site's physical and sensory attributes. Techniques like global illumination, shadow mapping, and Unreal Engine's foliage system are used to simulate realistic lighting, landscapes, and vegetation. The environment is further brought to life with animations of water and fire, incorporating particle systems and fluid dynamics for realism, accompanied by synchronized sound effects to create a fully immersive 3D experience.

Implementing and configuring the first-person character.

In the development of the virtual caravanserai, the implementation of a first-person character (FPC) signifies a pivotal shift towards direct player interaction with the virtual environment. Key considerations in this phase include fine-tuning movement mechanics and audio, like footstep sounds. Additionally, collision boxes and boundaries are strategically placed to define playable areas and prevent access to off-limit zones, ensuring uninterrupted gameplay.

Complementing this, the final touches involve configuring the first-person character blueprint and creating player guides, which are critical for refining player control and interaction within the game. These configurations are crucial to ensure that players feel a seamless connection to the virtual environment, enhancing their immersion and interaction with the game's elements. This phase includes the implementation of an on-screen guide for tuning camera settings, movement speed, interaction radius, and controls for various actions like fast walking, jumping, and zooming, thereby enhancing the overall gameplay experience (Figure 1).
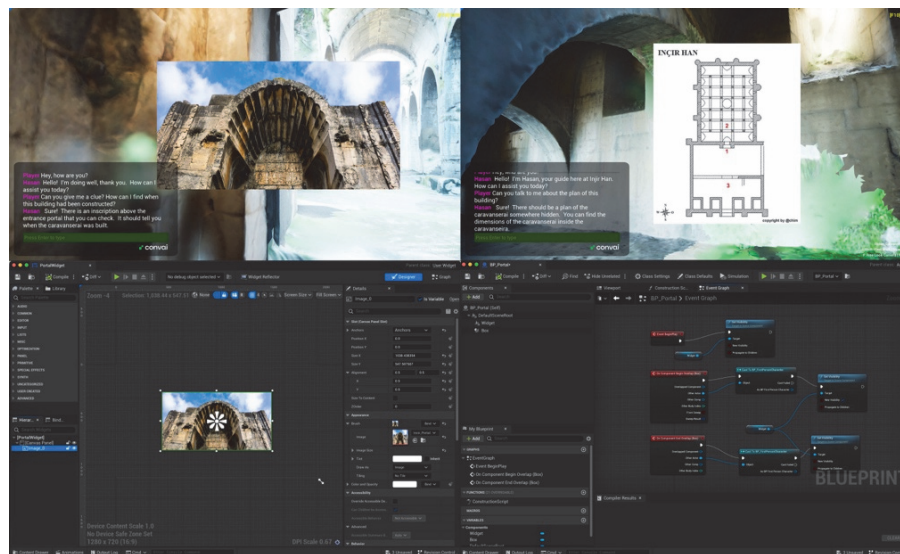
Figure 1
First-person character development process

Enhancing learning and engagement: interactive elements and user interface.

The development of interactive elements and a user-friendly interface in the virtual caravanserai game marks a significant phase, enhancing both the educational and engagement aspects of the gameplay (Figure 2).

Figure 2
Interaction and UI design

This stage is dedicated to integrating interactive educational content, employing pop-ups and other triggers to provide historical and cultural information to players. These interactive features are crucial for enriching the learning experience within the game. As players navigate through specific locations, information pop-ups, consisting of images or text boxes, are activated. These pop-ups appear based on the player's proximity to certain points of interest, facilitated by collision boxes and interactive triggers. Their design is executed using Unreal Engine's UMG (Unreal Motion Graphics) system, and the logic behind when and how these widgets

appear and interact with the player is defined using Blueprints, Unreal's visual scripting language.

This thoughtful integration of interactive elements aim to ensure a seamless, informative interaction, potentially enhancing the player's engagement and learning as they explore the virtual caravanserai.

Integration of AI in educational gamification: the role of Convai

Building on the developed groundwork, this segment of the paper delineates the implementation of an AI-driven interactive element within the virtual environment of the Incir Han Caravanserai project. The integration employed the Convai plugin and MetaHuman in Unreal Engine 5.2, aiming to enhance the interactive and educational dimensions of the gamified experience.

Convai (2024) stands for Conversational Artificial Intelligence. It is a conversational AI platform that allows for the creation and integration of AI-powered characters into digital environments, notably in Unreal Engine. This platform, accessible through a web-based interface, simplifies the process of character creation, providing users with an intuitive and user-friendly environment for crafting their AI characters. The platform is designed to facilitate the creation of AI characters with advanced conversational abilities. Convai provides tools for designing characters that can interact with users realistically and engagingly. This technology is particularly suited for applications in educational gamification, where interactive and immersive learning experiences are crucial. Furthermore, the real-time multilingual capabilities of Convai cannot be understated. They mark a significant advancement in making educational content universally accessible, allowing characters to communicate and interact with users across diverse linguistic backgrounds. This feature is not just an addition but a nod towards inclusivity, ensuring that educational gamification transcends geographical and cultural barriers.

Character creation.
In the Convai platform, the intricate process of creating AI characters for educational gamification begins with a detailed backstory development, crafting a comprehensive narrative for each character. This rich backstory is essential in making the character not just a digital entity but a relatable, authentic presence within the virtual environment (Vaez Afshar et al, 2023). The process continues by defining a wide range of actions and behaviors that the character can perform, such as gestures, facial expressions, and reactions to various in-game scenarios. The characters are further customized in terms of emotional responses, psychological states, and speaking style, encompassing voice tone and mannerisms. Personality traits, such as curiosity or assertiveness, are chosen to align with the educational objectives of the project. The visual aspect of the character is also given significant attention. This includes the character's physical appearance, clothing, and animations, all designed to be in harmony with the character's backstory and the thematic setting of the game in the educational content. Finally, once the character is fully developed, a unique Character ID is assigned by Convai, which is key to integrating the character into digital platforms like Unreal Engine (Figure 3).
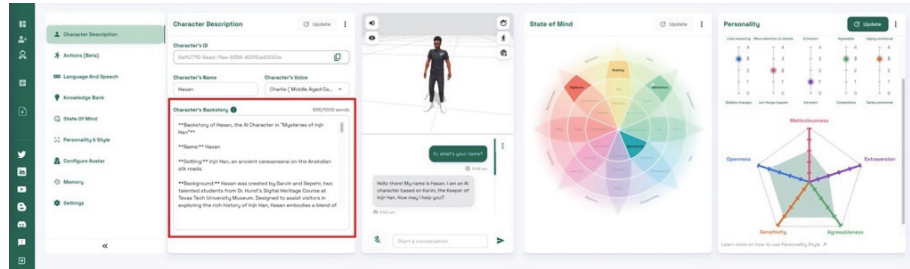
The AI character in this project, named Hasan, is a key educational tool. As a holographic guide, he provides historical information about the site and the Seljuk Empire, aiding exploration and learning about the caravanserai's history. His integration into the game enhances engagement and the effectiveness of educational gamification, demonstrating the transformative impact of AI characters in heritage education.

Integration of Convai plugin with Unreal Engine.
Incorporating the Convai plugin into the Unreal Engine environment is the next step. This integration is facilitated through the Engine's plugin management interface, where the Convai plugin is enabled and configured. Through an API key, the Convai plugin becomes an integral component of the Unreal Engine project, setting the stage for

creating AI-driven interactions that can enhance the user's experience.

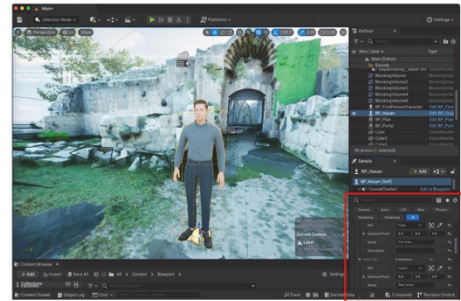**Enhancing educational gamification with MetaHuman framework.**
The integration of Convai with Unreal Engine, particularly when aligned with the MetaHuman (2024) framework, marks a notable innovation in educational gamification, providing characters with enhanced photorealism and expressive capabilities. MetaHumans, crafted with Unreal Engine's *Quixel Bridge*, set a high standard for realistic avatars, offering a perfect base for creating AI-powered interactions that greatly enhance gamified learning experiences. The realism of MetaHumans is enhanced by the ConvaiOVRLipSync plugin, which enables lifelike lip-syncing and speech mimicry, adding depth to verbal interactions in the virtual environment.

Dynamic interactions with AI characters in gamification.
The Convai platform amplifies the MetaHuman framework by adding a spectrum of complex capabilities, including a variety of action sequences and gestures that characters can execute, enriching the interactive experience. Actions within the Convai-enhanced MetaHuman framework can be initiated by natural language commands, providing a seamless and intuitive interaction that boosts user engagement. For example, asking a character, "Can you show me where travelers would rest?" or "Follow me to the courtyard" prompts a real-time response, enriching the educational and interactive elements of the experience (Figure 4).

Navigational intelligence in AI characters: NavMesh and NavLinkProxy.
For any AI character to navigate effectively within the Unreal Engine environment, including those enhanced by Convai, the implementation of navigation meshes (NavMesh) and navigation link proxies (NavLinkProxy) is essential. NavMesh in Unreal Engine is a pathfinding tool that allows AI characters to navigate intelligently within the game world by distinguishing between walkable areas and obstacles to determine the best routes. When a player asks a Convai character to "Follow me to the courtyard," it is the NavMesh that the AI uses to determine the best route to take, avoiding obstacles

and navigating the environment realistically. NavLinkProxy extends these capabilities by allowing AI characters to perform more complex maneuvers, such as jumping over gaps or moving up and down stairs, which the standard NavMesh may not cover. By integrating NavMesh and NavLinkProxy with the Convai character, developers ensure that the character's navigation is as advanced as its conversational abilities. This dual enhancement of cognitive and spatial awareness makes the AI characters in educational gamification not only informative and interactive but also smoothly integrated into the virtual world's ecosystem.

DISCUSSION AND CONCLUSION
This research project marks a significant advancement in heritage education by integrating AI and gamification with the rich history of the Silk Roads and the Incir Han Caravanserai. Utilizing Unreal Engine technology, the research has transformed traditional educational methods into an immersive, multi-sensory experience, creating a realistic 3D representation of historical sites. This innovative approach transcends conventional learning methods, deeply engaging users and cultivating a connection to history often unachievable through traditional methods.

Unreal Engine 5.2's advanced rendering and interactive tools provide a significant advancement in historical content presentation, emphasizing the increasing importance of digital literacy and technological proficiency in educational contexts. A key challenge in this research has been balancing historical accuracy with engaging gameplay, ensuring the gamified experience remains a credible educational tool while retaining the immersive qualities of a game.

Recognizing the critical importance of iterative testing and user feedback, this project highlights these elements as central to future studies. Although not yet implemented, continuous surveys and player testing are planned to measure user engagement, understand learning outcomes, and refine the game based on real-world feedback. This anticipated iterative process is essential to ensure that the educational content and game mechanics align with our intended educational objectives.

The project's success opens new avenues for future research in gamification and advanced visualization technologies across various historical and cultural contexts. It emphasizes the need for in-depth research into these methods' effectiveness in enhancing learning outcomes and user engagement. By providing interactive quizzes and AI-driven characters, the project aims to facilitate a collaborative and participatory educational environment, enhancing student engagement and promoting critical thinking.

This research contributes to digital humanities, educational technology, and cultural preservation, demonstrating the transformative potential of blending innovative technology with pedagogy. By serving as a model for future projects that aim to bring historical narratives to life, it not only enriches the educational landscape but also acts as a tool for preserving and disseminating cultural heritage. This approach promises a future where learning transcends traditional confines, evolving into an immersive, interactive journey that inspires a new generation and is accessible to a global audience.

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