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HOLOGRAPHIC TEACHER: STRATEGIES FOR ENHANCING THE EFFICIENCY AND ENGAGEMENT POTENTIAL OF PROGRAMMING STUDENTS THROUGH UNREAL ENGINE AND AI

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Abstract

This article presents a comparative analysis of the impact of using holographic technologies in higher education—particularly in Programming and IT fields—on learning effectiveness and student engagement. The study examines the advantages of holograms over traditional teaching methods, especially in enhancing spatial thinking and visualizing complex abstract concepts. The paper also explores in detail the use of Unreal Engine to create highly interactive and realistic content, as well as strategies for integrating artificial intelligence platforms such as ConvAI to transform holograms from static visual tools into dynamic, real-time interactive "intelligent tutor" agents. Additionally, real-time performance (low-latency) requirements, technical limitations, and issues of academic integrity are analyzed, and practical recommendations are provided for implementing holographic solutions in the IT domain.

Keywords: Holographic technologies, Higher education, Learning effectiveness, Student engagement, Unreal Engine, ConvAI, Artificial intelligence (AI), Real-time processing, Interactivity, Programming education, IT education, Immersive learning, Virtual instructors.

Introduction

Among innovative technologies in higher education environments, hologram technology offers special opportunities to deepen the learning process and increase student engagement potential. This technology is considered not only as

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a visual presentation tool, but also as a powerful instrument for explaining complex concepts, developing spatial imagination, and creating a deeper learning experience [4].

Modern research places significant emphasis on two main aspects of using this technology in education — learning effectiveness and student engagement potential. Several meta-analyses and empirical studies confirm that hologram technology (3DHT) has a strong positive effect on improving students' learning outcomes. For example, one meta-analysis calculated that 3DHT improves students' learning results with a standardized mean difference (SMD) value of 0.835, which indicates a large effect size[1]. Another meta-analysis has also clearly shown that Mixed Reality (MR), including holographic systems, is associated with improved learning outcomes compared to traditional pedagogical methods [4].

These findings scientifically support the potential of integrating hologram technology into the educational process to enhance real learning outcomes. In particular, holograms can be especially useful in complex and spatially oriented disciplines such as science, technology, engineering, and mathematics (STEM). They allow students to simultaneously view and analyze complex biological structures, chemical molecules, or physical phenomena from different angles, which helps develop spatial imagination and improves the level of understanding [2].

One of the most notable aspects of hologram technology is its ability to engage students. This technology is recognized for its "wow effect," which leads to feelings of admiration, curiosity, interest, and a desire to participate among students [5].

This "wow effect" does not remain only as a first impression; it also enhances the effectiveness of the learning process. Emotional engagement is crucial because it strengthens memory retention and makes long-term information retention more effective[6]. In projects such as HoloBoard, a vivid interaction and a high level

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of student engagement can be observed[7]. Mixed Reality technology has proven successful in increasing attention and interest in complex subjects such as anatomy learning[4]. In addition, hologram technology may also contribute to the development of emotional intelligence among students[10].

However, there are also certain limitations in applying this technology in education. For example, creating and operating holograms may require significant computational power[10].

Moreover, although hologram technology is more complex than simple visual effects, its practical application may involve technical issues such as latency, as well as the need for specialized skills for content creation[10].

Unreal Engine (UE), especially the UE5 generation, provides a powerful ecosystem of tools for creating modern interactive and realistic content to integrate hologram technology into educational environments. This engine is not only designed for visual effects but also includes a comprehensive set of resources for building complex, interactive, and realistic learning environments. With UE's next-generation rendering system (Nanite) and dynamic global illumination system (Lumen), photorealistic models can be created. Tools such as MetaHuman enable the easy creation of realistic characters[6].

This is especially important for developing virtual textbooks, historical figures, or complex physical systems. However, this level of realism comes at a cost: it requires substantial computational resources for real-time performance[9]. In Unreal Engine, tools such as the Blueprint visual scripting system allow even non-programmers to easily add interactivity[8].

For example, this enables functions such as allowing a student to view a hologram of themselves, walk around it, and test different conditions. In creating a small biology textbook, a model prepared in 3Ds Max was implemented in UE4[5], which demonstrates UE's integration with various 3D modeling software.

Modern game engines (including UE) use various mechanisms to optimize performance, such as predicting object states, rendering lower detail for smaller

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fragments, and using predictive systems to reduce latency (delay)[8]. This is critically important for ensuring real-time performance. Thus, Unreal Engine is not only a tool for visual effects but also a powerful platform for creating complex, interactive, and realistic educational environments. Its use in education enables bringing learning materials "to life" and fostering active interaction with students.

Table 1: Technologies and their significance in education

Technology	Quality / Capability	Educational Benefit
Nanite Rendering System	Photorealistic quality in real-time rendering	Creation of complex objects and virtual worlds, such as virtual archaeology sites or biological structures
Lumen Dynamic Global Illumination System	Automatic dynamic lighting and reflection effects	Enhancing depth perception and improving visual realism, e.g., simulation of natural phenomena
MetaHuman Creator	Fast and easy creation of photorealistic 3D avatars	Creating virtual teachers, historical figures, or experimental partners
Blueprints Visual Scripting	Ability to add interactivity without coding knowledge	Creating simple and complex interactions between students and holograms, such as quizzes or problem-solving tasks
Modular Architecture	Integration of various real-time interactivity and audiovisual generation technologies	Ensuring synergy between Unreal Engine and different educational tools (e.g., ConvAI)

The most innovative point of the research is transforming holograms from simple visual representations into interactive and responsive "teachers." Platforms such as ConvAI play an essential role in this process. Traditional holograms are often pre-recorded videos or animations with limited interactivity. However, with AI integration, holograms become "agents" capable of answering various questions, giving advice, and even engaging in debates. Unlike traditional Intelligent

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Tutoring Systems (ITS), this approach enables communication through both visual representation and conversational interaction.

Tools such as Effingo accelerate the creation of photorealistic 3D avatars, making it easier to integrate AI agents into holograms. The Convai platform, which works with Unreal Engine, enables NPCs (non-player characters) to be equipped with AI intelligence. This allows for the creation of a holographic teacher that can, for example, solve problems together with students or discuss programming algorithms. Although large language models (LLMs) such as ChatGPT have demonstrated the effectiveness of AI tutors, meta-analyses show that these systems produce varying effects depending on the subject area and level of interactivity.

The psychological impact of interacting with AI is also important. One study found that the level of interactivity of an AI agent (AI-led Supported Exploratory Questioning vs. Learner-Initiated Inquiry) significantly changes the nature of student learning interactions. In other words, an AI hologram should not only be a question-answering bot but also a partner that helps students formulate their own questions. However, it has also been found that excessive creativity or overly "socio-emotional" behavior of AI agents may distract students. Thus, AI integration takes hologram technology to the next level. It enables active learning processes, deeper personalization, and more meaningful interaction with students.

Real-time performance is the most critical factor for the educational effectiveness of hologram technology. If there is noticeable lag or instability in the system, all visual and interactive capabilities become ineffective. For an immersive experience, end-to-end delay (capturing, processing, transmission, rendering) must be less than 100 milliseconds. In some cases, such as haptic communication, this can drop to as low as 1 ms. In holographic teleconferencing, synchronization of sensor data is also crucial. Devices such as Microsoft HoloLens 2 have reported issues related to tracking latency and rendering delays.

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Several technical factors are important for reducing latency. GPU speed, model complexity, rendering resolution, and processing power are all interdependent and must be optimized together. XR streaming and networking technologies also require strong infrastructure to ensure real-time performance, which is directly linked to learning outcomes. A mixed reality simulator with total system latency below 20 ms has been shown to improve student learning speed by 32.4%. High-latency systems, on the other hand, lead to feelings of distrust and discomfort, which disrupt the learning process.

Therefore, real-time performance is not just an optional feature but a fundamental requirement for hologram technology in education. Projects that assume unrealistic speed constraints may not be effective. For this reason, the use of low-cost hardware or unoptimized software should be avoided. The study also places special emphasis on programming and IT fields, which is a very appropriate choice. In these fields, hologram technology opens far more possibilities than traditional teaching methods. Programming involves abstract concepts such as data structures, algorithms, and computer architecture. Through holograms, these concepts can be visualized and made interactive. For example, the execution process of an algorithm can be demonstrated through a hologram, allowing students to observe and "inspect" its changes in different states.

Unreal Engine itself is also a tool widely used in programming and IT. A holographic teacher created in Unreal Engine can interact with students within a virtual world. This enables more advanced AI-assisted teaching in VR classrooms.

AI-assisted development tools (AIDE) are already widely used in programming. A holographic teacher further personalizes these systems. Compared to systems like ChatGPT, a holographic teacher can visually present information, respond in real time, and guide students through hands-on interactions. This leads to deeper understanding of the material.

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Thus, in programming and IT education, hologram technology can be considered an ideal tool for concretizing abstractions, teaching practical skills, and transforming AI assistant systems into visual and interactive learning environments.

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