Humanizing Online Learning: The Role of AI+XR-Based Virtual Tutors in Adaptive Education

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Abstract. **The integration of Artificial Intelligence (AI) and Extended Reality (XR) in education has opened new possibilities for adaptive and personalized learning. Among these, Virtual Humans (VH), which are AI-driven XR avatars capable of real-time humanized interaction, have emerged as promising tools for content adaptation, emotional support, and learner engagement. This paper examines the roles of VH in fostering adaptive learning, emphasizing their capability to meet diverse learner needs through responsive, individualized content adaptations, based on a literature review. This study investigates the effectiveness of a VH-based system, *VirtualTutor*, developed to enhance online learning in a Computer Science course. A case study involving 265 undergraduate students evaluated the impact of the system on engagement, perceived usefulness, and comprehension. The results of this study are presented in this paper. Findings support the potential of VH to foster inclusive, scalable, and learner-centered educational environments, while also identifying key areas for system refinement and future research.**

Keywords: **AI-based Learning, Virtual Humans, Extended Reality, Adaptive Learning, Personalized Instruction, Virtual Tutors.**

I. Introduction

In the past years, the integration of Artificial Intelligence (AI) into educational technologies has significantly transformed how learning content is delivered and adapted to individual needs. Recent findings that rely on data-based AI brought new possibilities of applying AI-driven techniques in distinct learning contexts. One of the key developments in this field is the use of AI-based learning content adaptation, where the learning environment adapts itself and its contents in real time to a learner's abilities, disabilities, preferences, and pace. This adaptive approach has been shown to increase engagement and improve learning outcomes by providing personalized learning paths [1].

A particularly innovative application of AI in this domain involves the use of Virtual Humans (VH). They can be described as lifelike digital avatars capable of interacting with learners in real-time [2]. These virtual entities can serve as tutors or facilitators, enhancing the learning experience by simulating human-like communication, understanding learners' behavior, and offering tailored guidance [3]. VHs leverage natural language processing and machine learning techniques to make interactions dynamic, fostering a more immersive and personalized learning environment [4].

The role of VH in learning content adaptation extends beyond mere delivery of information. They are capable of emotionally engaging learners, offering encouragement, and adapting their communicational approach based on the learner's emotional state [5]. This emotional dimension is important, as motivation and affective states have been shown to significantly impact learning outcomes [6]. Furthermore, the use of VH in adaptive learning systems presents new opportunities for scaling personalized education, making it accessible to larger and more diverse student populations.

This study aims to investigate the potential of AI-powered Virtual Humans to support adaptive learning in online higher education settings. Specifically, it explores the integration of VH into an AI-based virtual tutoring system (VirtualTutor), focusing on their ability to personalize content delivery, enhance learner engagement, and improve perceived usefulness. The study also examines the system's pedagogical and technical features, assesses student perceptions, and identifies limitations and directions for future improvements.

II. Learning Content Adaptation

In the educational context, it is well known that not all students learn in the same way or under the same conditions of understanding — in reality, the learning process is individual and unique for each person, as indicated by various classical learning theories. According to Huang [7], these theories range from the Piagetian approach, which emphasizes that learning occurs through an active and individual process of knowledge construction, to the Vygotskian perspective, which acknowledges that the internalization of knowledge depends on each individual's unique capabilities, even when mediated by others. Ausubel [8] also contributes to this view by indicating that meaningful learning occurs when individuals engage in the learning process by aligning content with their own experiences and interests. Educational needs and student development are unique, and learning is influenced by personal characteristics such as personality, cognition, innate abilities, and the educational process itself.

Whether in the context of formal face-to-face, distance, or hybrid education at various educational levels, what is traditionally offered is a set of educational materials provided collectively and not in a personalized way [9]. This scenario stems from the impracticality of manually adapting content for each student, resulting in educational settings where instructional material is only partially effective, often failing to meet the individual needs of each learner. Content adaptation thus emerges as an inclusive alternative, as it can enhance learning for students with various profiles, including those with learning difficulties, dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), or other conditions who may benefit from educational materials presented in a simpler and more organized manner. In this way, it is possible to contribute to the development of educational environments that promote equity and maximize each student’s potential.

In this regard, the automation of educational content adaptation becomes an important element in addressing the growing demand for personalization, inclusion, and scalability in contemporary education. This approach is not new—often referred to as Adaptive Learning (AL) — and can be seen in several studies, such as those by Martin et al. [9], Li et al. [10], Rachmad [11], and Minn [12], to name just a few. Due to technological limitations, most of these studies implemented individualized delivery of pre-designed materials, based on conceptual prerequisites, self-declared or automatically detected learning preferences, or other aspects, by reorganizing content elements, suppressing certain parts, or providing additional content.

In the context of AL, in recent years, the need for inclusive education has gained significant attention, particularly in ensuring that educational content is accessible and adaptable to students of diverse backgrounds and abilities [13]. With advancements in technology, AL systems have emerged as a promising solution to address this challenge by tailoring educational content to meet the unique needs of each learner. These systems use data-driven approaches, including AI and Machine Learning, to analyze learners' interactions and adjust the complexity and format of the material accordingly [14]. This dynamic customization of content aims to provide all students, including those with disabilities, the opportunity to engage fully with the material and achieve success in their learning objectives [15].

The article titled *“Impact of Artificial Intelligence and Virtual Reality on Educational Inclusion: A Systematic Review of Technologies Supporting Students with Disabilities”* presents a systematic review of 48 studies published between 2015 and 2023 [16]. The findings highlight that both Artificial Intelligence (AI) and Virtual Reality (VR) have significant potential to enhance the educational inclusion of students with disabilities, with VR primarily contributing through immersive and interactive learning environments, while AI offers adaptive support, personalization, and accessibility features. Importantly, the review identifies gaps in empirical evidence, particularly regarding long-term effects, cross-disability applicability, and ethical considerations of these technologies. The results suggest that while the integration of AI and VR is promising for inclusive education, future research must focus on scalability, teacher training, and responsible innovation to ensure sustainable adoption.

Also, the article *Artificial Intelligence and Immersive Technologies: Virtual Assistants in AR/VR for Special Needs Learners* explores the integration of AI-powered virtual assistants within augmented and virtual reality environments to support learners with special needs [17]. The study highlights that such technologies enhance personalized learning by adapting to individual requirements, improving engagement, and fostering inclusivity. Results suggest that AI-embedded immersive tools can bridge accessibility gaps, offering real-time assistance, multimodal interaction, and tailored feedback. The findings also emphasize the potential of these tools to empower learners, promoting autonomy and active participation in educational contexts.

One critical aspect of content adaptation for inclusion is the ability to cater to learners with physical, cognitive, and sensory disabilities. Multimodal learning environments, which incorporate visual, auditory, and tactile elements, can significantly enhance the accessibility of content for these students. Studies have shown that such environments help reduce barriers by offering multiple ways for students to engage with the material, whether through text, speech, or visual aids [18]. For example, screen readers and captioning systems can assist visually and hearing-impaired learners, while interactive tools can support students with cognitive disabilities by providing step-by-step guidance through complex topics [18].

AI plays a central role in personalizing learning experiences for inclusion. Adaptive learning platforms that integrate AI can monitor student progress in real time, identify areas where they are struggling, and modify the content to provide additional support or alternative explanations. This approach ensures that students do not feel overwhelmed and can progress at their own pace [20]. By analyzing patterns in learners' behavior, AI systems can detect when a student may need more visual aids, additional examples, or a slower presentation of information to improve comprehension. These platforms are particularly useful for students with learning disabilities, as they can receive immediate feedback and support tailored to their needs [20].

Collaborative learning environments also benefit from adaptive content systems, especially in promoting inclusion among diverse groups of learners. In classrooms where students of varying abilities are working together, adaptive content can level the playing field by providing each student with personalized materials that match their skill level, while still allowing them to collaborate on group projects [22]. This not only fosters a more inclusive atmosphere but also encourages peer support and interaction, helping to break down the social barriers that students with disabilities or learning difficulties may face.

Finally, the role of educators in supporting content adaptation for inclusion cannot be understated. Teachers must be trained to use adaptive technologies effectively and to interpret the feedback provided by these systems to make informed instructional decisions [2]. Professional development programs focusing on inclusive teaching strategies, coupled with adaptive learning technologies, can empower educators to create environments that support the needs of all learners. By integrating adaptive systems with strong pedagogical practices, educators can ensure that students with diverse learning needs receive the appropriate scaffolding to succeed academically.

III. Virtual Humans

In recent years, the integration of VH in educational settings has gained significant momentum. These virtual entities, often embodied as avatars or digital characters, simulate human behavior and interaction, enhancing learning environments through personalized, interactive experiences. VH in education can be leveraged to deliver content, support problem-solving, and promote collaboration, creating an immersive learning experience that can cater to diverse learning styles and needs [23].

One of the primary advantages of VH in education is their ability to provide scalable, individualized instruction. Research indicates that virtual agents, when properly designed, can mimic human tutors by adapting to students' performance and offering feedback in real time. As a result, learners receive personalized guidance that aligns with their specific learning paths, making the educational experience more engaging and effective [5].

Moreover, the emotional and social presence of VH can positively influence learning outcomes. Studies have shown that students are more likely to engage with material when they feel emotionally connected to the agent [19]. This connection can foster a supportive learning environment, especially in scenarios where students may feel intimidated or anxious about engaging with human instructors. The ability of VH to simulate empathy and encouragement can also reduce student stress, contributing to better learning retention [22].

Another significant benefit is the role of virtual humans in collaborative learning environments. VH can serve as mediators or facilitators of group discussions, enhancing team dynamics and ensuring equitable participation. By simulating a neutral facilitator, these agents can help resolve conflicts, keep discussions on track, and encourage quiet students to contribute, thereby promoting deeper understanding through peer interaction [2].

However, despite these advantages, the use of VH in education is not without challenges. One of the most prominent issues is the complexity of designing agents that effectively replicate the nuances of human interaction. Building virtual humans that can understand and respond to the subtleties of human communication — such as body language, tone of voice, and context—is still an area of active research [24]. Moreover, ethical considerations surrounding the use of AI in education, such as privacy concerns and the potential for over-reliance on technology, must be carefully managed to ensure that Virtual Humans are used in a responsible and equitable manner [3].

In conclusion, the potential of VH to revolutionize education is promising. Their ability to offer personalized instruction, foster emotional connections, and mediate collaborative environments makes them a promising tool for modern educators. However, ongoing research is needed to address technical and ethical challenges to maximize their impact on learning outcomes.

IV. Literature review: examples of VH in education

A. AutoTutor (University of Memphis, USA)

AutoTutor [6] is an intelligent tutoring system, developed by University of Memphis (USA) that uses VH to teach complex subjects, such as physics and computer science. These VH engage in natural language dialogue with students, adapting the interaction based on the student's responses. AutoTutor has been shown to improve learning gains by providing individualized feedback and scaffolding during problem-solving tasks. Research demonstrates that AutoTutor's adaptive dialogues foster deeper understanding and retention of difficult concepts.

AutoTutor engages students by helping them explain complex topics such as Philosophy, Quantum physics, computer literacy, and critical thinking. It does this by analyzing their typed or spoken responses and building a cognitive model of their knowledge. This model helps AutoTutor tailor the interaction to each student's zone of proximal development, fostering personalized learning.

Affective AutoTutor advances this interaction by detecting and responding to students' emotional states alongside their cognitive responses. This emotional sensitivity helps struggling students achieve even greater learning gains, particularly those with low prior knowledge. Controlled experiments have shown that both AutoTutor and Affective AutoTutor consistently improve learning outcomes, often by one letter grade after just 30-60 minutes of use. Fig. 1 shows the interface of AutoTutor [6].

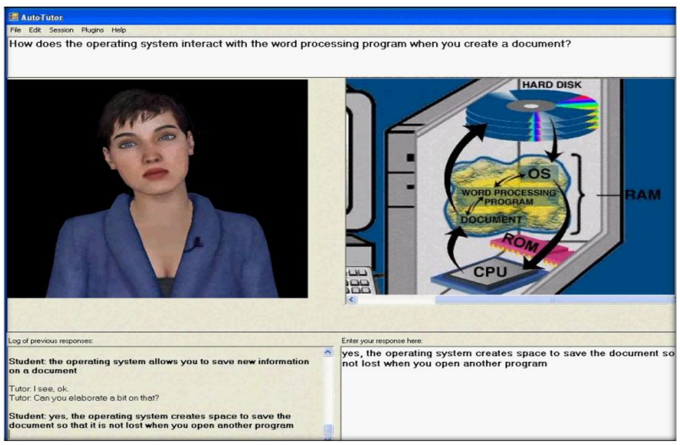

Fig. 1. AutoTutor interface (Source: [6])

B. TeachLivE (University of Central Florida, USA)

TeachLivE [25] is a mixed-reality teaching platform where pre-service and in-service teachers interact with virtual students, represented by avatars. These virtual students exhibit realistic behaviors, such as raising their hands, engaging in discussions, or misbehaving, helping teachers practice classroom management and instructional strategies in a controlled, risk-free environment. The program has been shown to improve teachers' confidence and classroom skills, especially in handling challenging student behavior.

TeachLivE [25] (Fig. 2) has been utilized in initial teacher education programs for over a decade, providing students with repeatable experiential learning opportunities. This innovative tool is now employed by more than 80 universities worldwide.

Fig. 2. TeachLivE (source: [25])

C. Betty's Brain (Vanderbilt University, USA)

Betty's Brain [26] is an intelligent learning-by-teaching environment that allows students to teach a VH, Betty, about complex scientific concepts. The system encourages students to learn by explaining and constructing knowledge models. Betty asks questions, and the students must ensure that the answers they provide are accurate and comprehensive. Research shows that students using Betty's Brain demonstrate significant improvement in critical thinking and knowledge retention compared to traditional learning environments. Fig. 3 shows the interface for Betty's Brain.

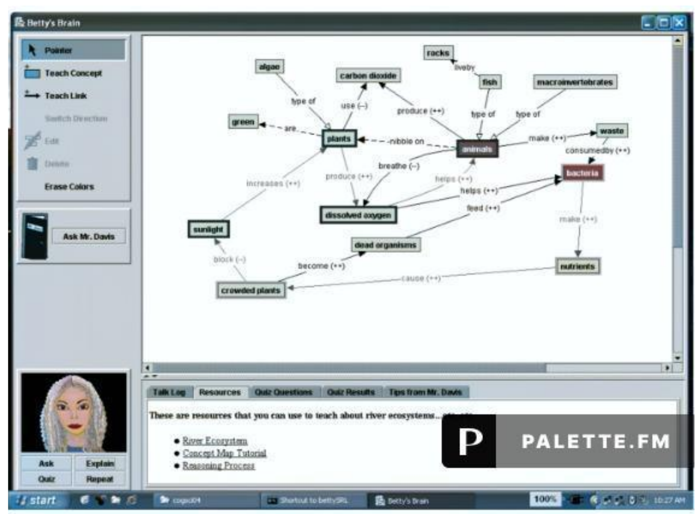

Fig. 3. Betty's Brain interface (Source: [25])

V. Case Study: VirtualTutor [University of Florida]

The case study here presented is about VirtualTutor, a project based on the Virtual People Factory (VPF), developed by one of the authors at the University of Florida. The VPF is a web-based system that enables users to interact with VHs (see Figs. 4a and

4b). Hosted on Amazon Web Services, the VPF supports multiple simultaneous users and operates within a standard web browser. It is compatible with a wide range of mobile and computing devices, thus accommodating students with varying processing capabilities and internet bandwidth.

The VPF employs both the Unity3D WebGL real-time player and pre-rendered videos of virtual humans hosted on a website. It utilizes predefined natural language conversational scripts and integrates large language models (LLMs) through access to ChatGPT. The natural language dialogue system leverages Google DialogFlow CX for intent recognition and the management of virtual agent responses, animations, and audio files.

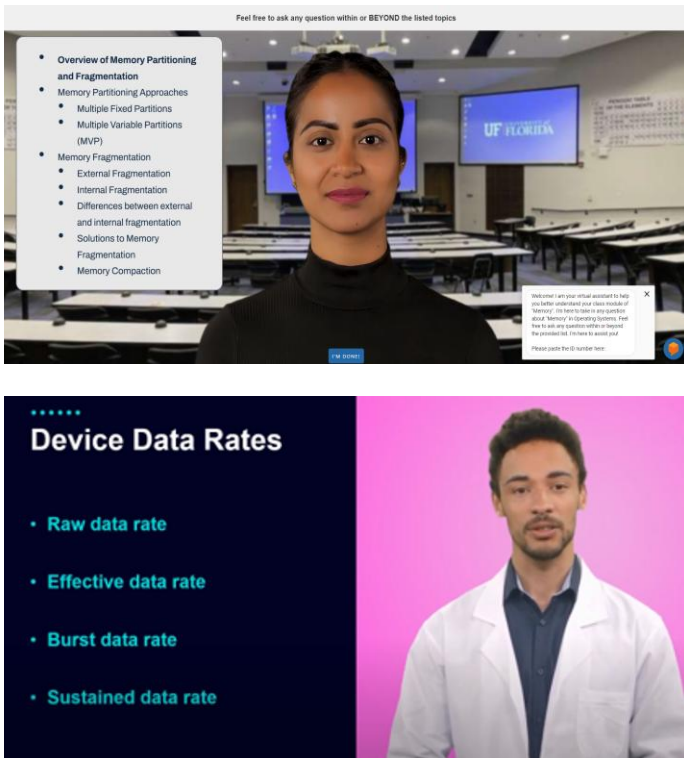

Fig. 4a and 4b. VirtualTutor avatar used in a Operating Systems course

The VPF supports both pre-recorded voice and text-to-speech (TTS) services, such as Google Text-to-Speech and Descript's Overdub. Agent animations can be either pre-recorded or generated in real time, including lip-syncing and hand gestures. The system offers multiple modes of interaction, including multiple-choice buttons, free text input, and voice-based communication. To date, hundreds of users have received personalized interactions through the VPF. Additionally, the platform supports integration with Learning Management Systems (LMS).

A pilot study conducted by one of the authors at the University of Florida in the fall of 2023 examined the role of VirtualTutor in adapting learning content to enhance online education in an Operating Systems course in Computer Science. Designed to augment pre-recorded lectures for online students, this AI-based virtual tutor provided customized summaries and explanations before and after the instructor's presentation of each topic, adapting the content to improve comprehension and engagement. Students could interact with the tutor directly, asking questions to clarify or expand on the material. The tutor's conversational model utilized Google Dialogflow [27] for intent-based responses, with ChatGPT [28], a large language model, as a fallback to handle questions outside of predefined responses.

To assess the effectiveness of this AI-based content adaptation, 265 students watched a 15-minute pre-recorded lecture that integrated the VH's adaptive summaries and explanations. Evaluations focused on engagement, the perceived utility of the virtual tutor, and its impact on the online learning experience. Results showed that 62% of students found the virtual tutor useful, with 75% reporting a more enjoyable experience due to the tutor's adaptive interaction. Additionally, 73% indicated that the supplemental content and interactive capabilities enhanced their understanding of the material - these results are depicted in Fig. 5. Student feedback highlighted the VH's role in adapting content to student needs, with comments such as, "Having a virtual assistant supporting the video is definitely better, more engaging, and enjoyable," and, in contrast to a text-based chatbot, "I am a more engaged learner when I can see someone speaking to me". Another student noted, "The summaries by the virtual human offered an additional perspective on the topics, which helps a lot."

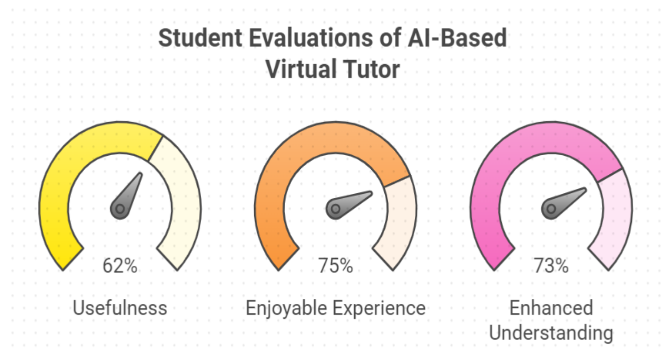

Fig. 5. Evaluation of *VirtualTutor*, in %

According to the results shown in Fig. 5, the key results are:

- 62% of the students responded positively about VirtualTutor's usefulness, but while a majority found the system useful, 38% did not. This suggests that the system may not be meeting the needs of a significant portion of students.

- The majority (75%) had a good experience, which indicates a solid foundation in usability and design.
- The fact of 73% of students having reported that the experience with *VirtualTutor* enhanced learning, which is a strong indicator that students perceive real educational value.

A. Limitations

Despite the promising results obtained with the VirtualTutor, several limitations must be acknowledged, which may have influenced both the scope and generalizability of the findings.

First and foremost, the case study was conducted in a single academic course — an undergraduate Operating Systems class — within a Computer Science program at a university located in the United States. This inherently narrows the cultural, disciplinary, and demographic representativeness of the study. Students in this course may share similar technological fluency, learning preferences, or cultural norms around digital education, which can positively bias their engagement with virtual human-based systems. Thus, generalizing the results to learners from other academic disciplines, institutions, or sociocultural backgrounds requires caution. Future work should involve replication studies in more diverse geographical, cultural, and curricular contexts to validate and broaden the conclusions.

Another important limitation lies in methodological design, particularly regarding the evaluation instruments. The assessment relied primarily on quantitative indicators derived from closed-ended survey questions. While these provided valuable insights into perceived usefulness, engagement, and enjoyment, they did not allow for deeper exploration of students' motivations, frustrations, or contextualized experiences with the VirtualTutor. The absence of complementary qualitative analysis — such as open-ended responses, interviews, or usage analytics — restricts the interpretive richness of the findings and limits the understanding of why certain students (notably 38%) did not perceive the tool as useful.

Regarding the perceived usefulness gap, the usefulness rate of 62%, while promising, indicates that over a third of the students did not find the VirtualTutor beneficial to their learning. This reveals a gap that must be addressed before the system can be considered robust for large-scale implementation. It raises questions regarding the adaptability of the virtual human to varied learner needs, the clarity and relevance of the summaries and feedback provided, and the degree of interactivity perceived by the user. This limitation suggests the need to refine both the pedagogical strategies and the user experience design of the VirtualTutor, incorporating adaptive mechanisms that are more sensitive to individual learning profiles.

Moreover, the fact that 25% of the participants did not report a positive user experience invites further investigation into possible technical issues, interface design limitations, or mismatches between interaction modalities and user expectations. These aspects may have interfered with both engagement and learning efficacy, particularly among students who are less accustomed to XR environments or who prefer more traditional forms of feedback.

Finally, the study did not systematically address the long-term cognitive, emotional, or ethical impacts of interacting with AI-powered virtual humans in educational settings. As these systems become increasingly sophisticated and embedded in learning environments, concerns about data privacy, emotional dependency, algorithmic bias, and transparency must be investigated with rigor.

VI. Final Considerations

The not-so-new advent of technology-based learning brought plenty of challenges to educators and developers, which range from the digital gap that is still present in many countries to the creation of more immersive, user-friendly platforms and environments. Thus, initiatives that look to enhance the ease of use and the enjoyability of learning, for instance when humanizing the interaction of learners and teachers in technology-based environments, must be pursued.

The integration of AI in educational settings, particularly through adaptive content delivery in learning environments and the use of VH to perform it, has shown promising results in personalizing learning and enhancing engagement. AI-based learning content adaptation not only addresses the diverse needs of students but also supports inclusive education by tailoring materials to different deficiencies, abilities and learning needs. VH can act as dynamic, humanized tutors and facilitators, adding an emotionally engaging and responsive element to the learning process. This has been shown to improve motivation and retention. The use of these technologies exemplifies a shift toward a more learner-centered, flexible, adaptive education, paving the way for more scalable, effective approaches to individualized learning.

The implementation of VirtualTutor demonstrates significant potential in enhancing online education through personalized, humanized and adaptive learning experiences. The VirtualTutor effectively engages students by providing real-time, customized feedback and summaries, which helps clarify complex topics and boosts learner engagement. Students reported higher comprehension and enjoyment levels due to the adaptive support from the VH, indicating the tool's capability to address diverse learning needs. The results suggest that VirtualTutor could be a powerful supplement to traditional instruction, particularly in online settings where direct instructor interaction is limited, especially for large, diverse classes.

To fully leverage the potential of AI in education, further research is needed to optimize the balance between AI-driven and human-led instruction. Enhancing the emotional intelligence of VH, along with their contextual responsiveness, would make interactions more meaningful, humanized and personalized. Future work should also assess the long-term impact of AI on learning outcomes across different academic fields and age groups, from different social extracts, identifying and solving any gaps in efficacy. Additionally, addressing ethical concerns such as data security, the potential psychological impact of virtual interactions, and equitable access will be crucial to ensure that AI-driven educational tools are beneficial and responsibly integrated into learning environments.

As explored above, an important limitation of the study concerns the context in which the case study was conducted. It was carried out within a single course (Computer Science) at a university located in the United States, with well-defined cultural characteristics. Expanding this study to other cultural, geographical, and academic contexts is a direction for future work and new research findings.

Another limitation which was considered relates to the evaluation instruments used, as they are heavily quantitative in nature, which hinders a more in-depth analysis of qualitative aspects—particularly those associated with the low perceived usefulness rate (62%).

In this sense, while the VirtualTutor system is positively received, increasing its perceived usefulness should be a priority. Enhancing adaptive features, user experience (UX) design, and instructional strategies can help close the gap between a good experience and a demonstrably useful learning tool. About the UX of the XR model, it must be investigated those 25% who did not report a good experience—perhaps interface issues, technical glitches, or lack of engagement. It should be considered improving user interface (UI), interactivity, and feedback mechanisms. Concerning the learning enhancement, it is mandatory to refine pedagogical strategies — perhaps incorporate more active learning techniques, real-time feedback, or scaffolding. Shortly, analyze which features students found most beneficial and expand on them.

Other future research should focus on refining VirtualTutor 's interaction capabilities to capture and respond to a broader range of learner behaviors and questions. Enhancing the model's natural language processing could allow for more nuanced, contextually aware interactions. Additionally, exploring VirtualTutor's effectiveness across varied disciplines and learner demographics would provide valuable insights into its adaptability and impact. Ethical considerations, such as data privacy and the influence of extended AI interactions on learning behavior, should also be a priority, ensuring VirtualTutor is used responsibly and equitably across educational settings.

Although the VirtualTutor system demonstrates great potential, further improvements and broader investigations are necessary to ensure its effectiveness, inclusivity, and scalability across diverse educational scenarios.

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