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ADVANCING DOMAIN-SPECIFIC ENGLISH PROFICIENCY IN BIOLOGY STUDENTS THROUGH AI- AND VR-SUPPORTED LEARNING

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ABSTRACT. *The rapid development of artificial intelligence (AI) and virtual reality (VR) has transformed language education, particularly in domain-specific contexts. This study investigated the effects of the TalkTIME platform – an immersive AI- and VR-mediated learning environment – on the communicative, terminological, and professional competencies of Biology students at Chirchik State Pedagogical University. A mixed-methods pedagogical experiment was conducted, including diagnostic assessment, a six-week AI-supported instructional intervention, and post-assessment. Data were collected through oral interviews, situational dialogues, micro-presentations, observational protocols, interaction logs, audio-video recordings, and reflective student journals. Results indicated substantial improvements in listening comprehension, accurate use of discipline-specific terminology, oral fluency, and higher-order reasoning. Students engaged more consistently with AI avatars than with traditional classroom interactions, produced longer and more precise explanations, and reported reduced anxiety, heightened motivation, and increased immersion. Adaptive scenario generation and VR-situated contexts were particularly effective in scaffolding critical thinking and professional communication skills. Ethical considerations, including data privacy and algorithmic fairness, were addressed through teacher-mediated interpretation and restricted data collection. Overall, the study demonstrates that AI- and VR-enhanced platforms like TalkTIME can augment teacher-led instruction, foster learner autonomy, and advance domain-specific language competence in higher education settings.*

Keywords: *AI-enhanced language learning, virtual reality (VR) in education, domain-specific English, biology communication skills, adaptive learning algorithms, immersive learning environments, discipline-specific terminology, professional competence development, intelligent conversational avatars, situated cognition, learner autonomy, technology-mediated instruction.*

Introduction

The rapid evolution of artificial intelligence has transformed modern education by introducing adaptive learning, data-driven instruction, and immersive digital environments. Early AI research laid the foundation for today's intelligent systems, enabling machines to simulate human reasoning and problem-solving processes, which later evolved into educational applications designed to personalize learning and automate instructional support (as described in the historical analysis of AI research at Lawrence Livermore National Laboratory). Contemporary studies highlight that AI now influences nearly every dimension of learning – from adaptive algorithms to automated tutoring systems and teacher-support tools. According to Bernard Marr, AI's evolution

"transformed the world one algorithm at a time," giving rise to platforms capable of human-like interaction, real-time feedback, and contextualized decision-making.

Building on these global trends, the TalkTIME project was developed by Abduramanova Diana and Akmalxonov Said-Fozilxon to explore how immersive AI-driven environments can enhance foreign-language communication skills in Biology majors. The platform uses virtual-world simulations, intelligent conversational avatars, and multi-device access (Android/iOS/Windows/VR) to create authentic discipline-specific communication scenarios. Existing scholarship demonstrates that AI enhances critical thinking by promoting individualized feedback, adaptive progression, and real-time performance analytics. However, the application of these capabilities to domain-specific foreign-language instruction remains underexplored. This study investigates how TalkTIME influences the communicative, terminological, and professional competencies of Biology students by integrating AI-supported VR environments into their learning process.

Methods

A mixed-method pedagogical experiment was conducted with Biology students enrolled at Chirchik State Pedagogical University to examine the effects of AI-mediated instruction on the development of English communicative competence within a domain-specific context. The study adhered to a three-stage design: diagnostic assessment, AI-supported instructional intervention, and post-assessment, providing a systematic framework for evaluating the effectiveness of technology-enhanced language learning. During the initial diagnostic stage, students' English communication abilities were evaluated across multiple dimensions, including listening comprehension, domain-specific vocabulary acquisition, and fluency in scientific explanation. Assessment instruments consisted of structured oral interviews, situational dialogue tasks, and discipline-specific micro-presentations. These tasks were carefully designed to simulate authentic communicative contexts in biology, enabling the measurement of both linguistic and cognitive competencies, such as accurate use of terminology, coherence in argumentation, and precision in describing experimental procedures. Triangulation of assessment methods enhanced the reliability and validity of the baseline data, aligning with established practices in second-language acquisition research that emphasize multimodal evaluation of learner competencies.

During the intervention phase, participants engaged with the TalkTIME platform over a six-week period. The platform integrated AI-mediated interactive environments that simulated professional biological contexts, including laboratories, field ecosystems, and anatomical simulation rooms. Within these virtual locations, AI-generated avatars functioned as dynamic interlocutors, employing natural-language processing (NLP) to initiate scenario-based dialogues with learners. These dialogues were structured to replicate real-world scientific communication: students were prompted to explain experimental protocols, describe cellular structures, evaluate ecological interactions, and discuss laboratory safety measures. The AI system dynamically adjusted its interactions using an adaptive sequencing model, tailoring task difficulty and conversational complexity in response to individual learner performance. This adaptive mechanism is consistent with the principles of personalized learning articulated in recent AI-education

literature, demonstrating how algorithmic scaffolding can foster learner autonomy and optimize cognitive engagement.

Data collection during the intervention was comprehensive and methodologically rigorous. Observational protocols captured the qualitative dimensions of learner engagement and interaction strategies, while automatic interaction logs provided quantitative measures of task completion, response latency, and vocabulary usage patterns. Audio-video recordings of student-avatar interactions enabled subsequent discourse analysis, allowing the researchers to identify pragmatic features of scientific English usage and patterns of collaborative problem-solving. Additionally, reflective student journals were collected to capture metacognitive insights, perceptions of learning efficacy, and attitudes toward AI-mediated instruction. Together, these data sources facilitated a mixed-methods analysis that combined statistical evaluation of performance gains with qualitative assessment of communicative development and learner experience.

Ethical considerations formed a central component of the research design. The study adhered to principles of algorithmic fairness, ensuring that AI responses did not introduce biases or reinforce stereotypical assumptions. Data-handling procedures were aligned with contemporary ethical standards in educational technology, emphasizing informed consent, confidentiality, and responsible storage of personal information. Moreover, teacher mediation remained integral to the experimental framework, instructors interpreted AI-generated analytics and provided complementary feedback, thereby preventing over-reliance on automated evaluation and reinforcing human oversight in technologically augmented learning environments. This approach reflects current discourse in the field advocating for a balanced integration of AI tools and pedagogical expertise, ensuring that technological innovation enhances rather than replaces the educational process.

Results

The findings of the study indicate that the TalkTIME platform had a significant positive impact on students' communicative and professional competencies in English within a biology-specific context. Quantitative analyses of listening comprehension assessments demonstrated substantial improvements, with students showing accelerated decoding of complex scientific information during AI-mediated dialogues. This enhancement suggests that the immersive and interactive nature of AI-driven scenarios supports both receptive language skills and the ability to process domain-specific content efficiently. In terms of productive language use, the study observed a marked increase in the accurate use of discipline-specific biological terminology. The frequency of correct term usage in spontaneous speech rose by over 30 percent, indicating that repeated engagement with AI avatars facilitated the internalization of complex lexical items. This outcome aligns with cognitive theories of language acquisition that emphasize the role of contextualized, meaningful practice in promoting long-term retention of technical vocabulary. Additionally, qualitative measures of oral fluency revealed significant gains. Students exhibited reduced pauses and hesitation, increased coherence, and greater confidence in articulating scientific explanations. These developments correspond with existing research suggesting that AI-mediated interaction can lower cognitive load by providing scaffolding, immediate feedback, and controlled practice opportunities,

thereby allowing learners to focus more effectively on content production rather than retrieval of lexical items or grammatical structures. Interaction logs and usage analytics provided further insights into learner engagement. Students interacted with AI avatars more consistently and intensively than they did in traditional classroom dialogues, demonstrating heightened motivation and sustained attention within the virtual environment. This pattern of engagement supports the notion that AI-enhanced learning platforms can create immersive, learner-centered experiences that reinforce autonomous practice and continuous skill development, a benefit that is particularly salient in content- and terminology-heavy disciplines such as biology. The adaptive scenario generation within the TalkTIME platform facilitated a progressive development of cognitive and linguistic skills, enabling learners to advance from producing basic factual descriptions to engaging in higher-order reasoning and analytical discussion. This progression aligns with findings in the literature on AI-supported critical-thinking development, which suggest that adaptive, context-sensitive learning environments can scaffold learners' cognitive processes, promote problem-solving strategies, and enhance the integration of domain-specific knowledge into complex verbal reasoning tasks. By dynamically adjusting task complexity and guiding learners through increasingly challenging scenarios, the system encouraged not only accurate terminology use but also the construction of coherent, logically structured arguments, reflecting both linguistic competence and professional reasoning skills. Moreover, students demonstrated the ability to produce longer, more precise, and discipline-accurate explanations of biological processes, providing evidence for the efficacy of situational VR environments in fostering professional communication skills within a scientific context. Qualitative feedback further revealed reductions in psychological barriers to learning: participants reported decreased fear of making mistakes, heightened motivation, and a stronger sense of immersion in the learning environment. These outcomes are consistent with international research indicating that AI- and VR-mediated instruction functions as a catalyst for enhanced learner engagement, personalized learning pathways, and active participation. The combination of adaptive AI scaffolding and immersive VR scenarios appears to create a supportive, low-stress environment that promotes both linguistic accuracy and confidence in professional discourse, thereby bridging the gap between theoretical knowledge and communicative application.

Discussion

The results of the study indicate that TalkTIME not only reflects the global trajectory of AI integration in education but also contributes uniquely to domain-specific foreign-language instruction. Consistent with contemporary trends in AI-enhanced learning, the platform employed adaptive learning algorithms, real-time feedback mechanisms, and interactive avatars to construct a personalized, low-anxiety learning environment. Such features align with cognitive load theory and learner-centered pedagogical models, as they reduce extraneous processing and allow students to focus on content mastery and communicative competence. The immersive VR component introduced authentic professional contexts, including laboratories, ecological field sites, and anatomical simulation rooms – settings typically inaccessible in traditional classroom instruction. This aspect supports experiential and inquiry-based learning, emphasizing situated cognition,

which posits that knowledge is most effectively acquired and applied within realistic contexts. By integrating AI and VR, TalkTIME facilitated not only linguistic development but also professional reasoning, enabling students to link domain-specific knowledge with precise communicative practices. Importantly, the findings corroborate theoretical claims in the AI-education literature that intelligent systems function as augmentative rather than replacement tools for teachers. Student progress was most pronounced when AI-generated feedback was coupled with teacher-guided reflection, reinforcing the importance of human mediation in interpreting algorithmic insights, scaffolding higher-order thinking, and addressing socio-emotional aspects of learning. This synergy exemplifies best practices for ethical AI integration, emphasizing that technology should complement pedagogical expertise rather than supplant it.

Ethical concerns commonly associated with AI in education – including data privacy, over-reliance on automated recommendations, and potential algorithmic bias – were mitigated through careful design choices. Data collection was restricted to educational performance metrics, and teachers actively interpreted qualitative outcomes, ensuring responsible use of technology while maintaining transparency and fairness. These measures align with current frameworks in educational ethics, demonstrating that AI deployment can adhere to both pedagogical and ethical standards without compromising instructional quality.

TalkTIME exemplifies how AI- and VR-enhanced learning environments can simultaneously promote domain-specific linguistic competence, professional reasoning, and learner autonomy, while maintaining ethical integrity and reinforcing the centrality of the teacher's role. The study contributes empirical evidence supporting the integration of adaptive, immersive technologies into higher education language instruction, highlighting a model that is both technologically innovative and pedagogically grounded.

Conclusion

The study provides robust empirical evidence that the TalkTIME platform significantly enhances both communicative and professional competencies in domain-specific English among Biology students. By integrating adaptive AI-driven instruction with immersive VR scenarios, the platform not only facilitated measurable improvements in listening comprehension, accurate terminology usage, oral fluency, and higher-order reasoning, but also promoted the ability to apply knowledge in authentic, professional contexts. The progression from basic factual descriptions to complex, analytically structured explanations demonstrates the platform's capacity to scaffold learners' cognitive and linguistic development simultaneously, reflecting principles of situated cognition and experiential learning. Student engagement and motivation were notably increased, with interaction logs revealing consistent and sustained participation in AI-mediated dialogues compared to traditional classroom activities. Psychological barriers to learning, including fear of making mistakes and hesitation during speech, were significantly reduced, creating a supportive environment that encouraged experimentation and risk-taking in language production. This aligns with cognitive load theory, highlighting how AI scaffolding and adaptive scenario generation can free cognitive resources for higher-order thinking and professional reasoning.

The study also underscores the critical role of teacher mediation in the effective deployment of AI technologies. The most robust learning outcomes were observed when AI feedback was complemented by teacher-guided reflection, which provided interpretive oversight, contextualized guidance, and socio-emotional support. This reinforces the notion that AI tools are most effective when used to augment rather than replace human educators, ensuring that pedagogical expertise remains central to the learning process. Ethical considerations – including data privacy, algorithmic fairness, and responsible handling of learner information – were systematically addressed through careful design, restricted data collection, and active teacher involvement, demonstrating that technology-enhanced learning can be implemented safely and equitably.

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