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Can 3D Virtual Worlds Be Used as Intelligent Tutoring Systems to Innovate Teaching and Learning Methods? Future Challenges and Possible Scenarios for Metaverse and Artificial Intelligence in Education †

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Abstract

The integration of Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) represents a transformative advancement in education, combining immersive, interactive learning with AI-driven personalization. This study explores the synergies between these technologies, analyzing their benefits, challenges, and applications in domains such as medical training, STEM education, and language learning. Findings highlight their shared characteristics of adaptability, real-time feedback, and collaborative learning. However, challenges such as computational demands, pedagogical complexity, and ethical concerns must be addressed. Future research should focus on hybrid models leveraging blockchain, IoT, and augmented reality to enhance adaptive and scalable learning experiences.

Keywords: virtual worlds; intelligent tutoring systems; adaptive learning; artificial intelligence in education; immersive learning environments

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1. Introduction

The evolution of digital technologies is reshaping educational methodologies, fostering interactive, adaptive, and personalized learning environments. Among these innovations, Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) have gained increasing attention due to their potential in enhancing student engagement and optimizing learning outcomes. Virtual Worlds offer immersive, risk-free environments where learners can develop critical life skills such as problem-solving, collaboration, and adaptability. On the other hand, Intelligent Tutoring Systems leverage Artificial Intelligence to provide real-time feedback, adjust instructional content dynamically, and create personalized learning experiences tailored to individual needs [1].

Recent advancements in adaptive learning systems and metaverse-based education highlight the potential for integrating these two technologies to create highly engaging and effective educational frameworks [2–5]. Adaptive learning environments in the metaverse

facilitate personalized instruction, allowing students to interact with digital replicas of real-world objects, explore complex scenarios, and receive AI-driven guidance tailored to their learning styles and progress. Moreover, the Internet of Things (IoT), Mixed Reality (MR), and AI-powered Virtual Assistants have further enhanced the ability of Virtual Worlds to function as adaptive tutoring environments [6,7].

Based on what has been described so far, the aim of this study is to investigate the literature regarding the use of Virtual Worlds and Intelligent Tutoring Systems in the educational field, identifying how Virtual Worlds can be used as Intelligent Tutoring Systems, innovating teaching as a new method that facilitates learning.

Therefore, this research was guided by the formulation of several research questions. First, the investigation sought to determine the extent to which the scientific literature contains studies that associate the use of Virtual Worlds and Intelligent Tutoring Systems with educational innovation and as learning support tools. Second, attention was focused on evaluating the adaptive characteristics of 3D Virtual Worlds built on a constructivist basis and their potential use in education as Tutoring Systems. Finally, this study aimed to explore whether Virtual Worlds could be considered valid devices for use in education, including in combination with Intelligent Tutoring Systems as a tool for educational innovation and with reference to adaptive learning based on the use of artificial intelligence in the Metaverse.

This study also explores how the phenomenological approach can help define technological innovations that drive student-centered, data-driven learning environments [1,8].

2. Methods

This study explores the potential of Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) in education, analyzing their characteristics, benefits, and challenges.

To achieve this, a systematic literature review was conducted according to the Prisma 2020 methodological framework [9] to ensure as complete and transparent reporting as possible of our methods and results as detailed in the following sections.

2.1. Information Sources and Search Strategy: Steps for ARTICLE Selection

The literature review was conducted on articles published between 2018 and 2025. Article selection was conducted in accordance with these criteria, and bibliographic analyses were performed on three databases—Scopus, Google Scholar, and PubMed—in a first phase from 20 November 2024, to 3 February 2025, and subsequently in a second review phase from 1 July 2025, to 22 July 2025, to identify relevant publications investigating the application of VW and ITS in education and in relation to adaptive learning. Empirical studies, including case studies, experimental research, and literature reviews, were considered.

The selection of these databases was based on their internationally recognized impact indices [10,11].

It should be noted that numerous terms are used in the educational literature to describe this new form of technology. On the one hand, these terms highlight the different existing typologies; on the other, they contribute to a fragmented understanding of the evolution of virtual worlds, based on both technical aspects and experiential dimensions.

Among the various expressions present in the literature we can include: virtual world (VW), virtual environment (VE), multi-user virtual environment (MUVE), massive-ly-multiplayer online (role-playing) game (MMO(RP)G), immersive virtual world (IVW), immersive world, immersive online environment, 3D virtual learning environment, open-ended virtual worlds, simulated worlds, serious virtual world, social virtual world, synthetic virtual world and virtual learning environment (VLE) [12].

To avoid misunderstandings related to possible conceptual misunderstandings, in this study the term Virtual Worlds refers specifically to 3D Learning Virtual Worlds (3D-

LVW), which are immersive three-dimensional environments designed according to the principles of constructivist pedagogy, aimed at supporting active, contextualized, and meaningful learning. These environments place the student at the center of the educational process, promoting learning by doing and autonomous exploration, in line with Jean Piaget's theories on cognitive development [13] and Lev Vygotsky's concept of the zone of proximal development [14], which emphasizes social interaction and the role of mediation in learning processes.

3D-LVWs enable learning through immersive experiences and simulations, offering a dynamic space in which students can manipulate objects, experience realistic scenarios, and interact with other avatars or digital agents. In this sense, they also fully respond to Jerome Bruner's [15] vision, according to which learning is facilitated when anchored in a narrative, exploratory, and culturally situated context. Furthermore, they follow the epistemological approach of Seymour Papert [16], who in his constructionism states that knowledge is constructed through the active design and manipulation of digital artifacts.

The search strategy was based on the use of fundamental concepts regarding the object of this study ((3D Virtual Worlds OR Intelligent Tutoring Systems) AND (Teaching OR Learning OR Adaptive Learning)) and the search questions using Boolean operators (AND, OR) with simple operators using parentheses in the search string [17].

In an initial screening phase, search strings were limited to the presence of search terms in the titles, abstracts, and keywords of the articles. Only studies published between 2018 and 2025, open access, and written in English, were considered.

All identified articles were collected. The initial search returned 1366 articles and no duplicates or retracted publications were found. The final number of studies included in the analysis was 1366. All articles were independently reviewed by three authors and were selected for the screening phase only if deemed eligible by all parties.

The second step was the screening phase; the articles were examined again, always with reference to the title and abstract, according to the inclusion and exclusion criteria (Table 1), thus leading to the selection of 76 articles.

Table 1. Inclusion criteria used in the screening and inclusion phase.

Inclusion Criteria	Exclusion Criteria
Studies evaluating the use of 3D Virtual Worlds in learning and teaching	Articles not meeting the inclusion criteria
Studies evaluating the use of Intelligent Tutoring Systems in learning and teaching	Duplicate articles
Case studies or good practices on the use of Virtual Worlds in learning and teaching	Articles not written in English
Case studies or examples of good practices on the use of Intelligent Tutoring Systems in learning and teaching	Conference proceedings, lecture proceedings, book chapters, and other non-peer-reviewed publications
Studies, case studies, or examples of good practices on the combined use of Virtual Worlds and Intelligent Tutoring Systems in learning and teaching	Articles written before 2018
Original study designs (randomized, controlled, quasi-experimental and observational) that allow the evaluation of the effect of the intervention	Narrative reviews and/or meta-analyses that do not strictly meet the review inclusion criteria
Reviews or meta-analyses, if they clearly report specific results, demonstrate with well-defined parameters an effect of the use of Virtual Worlds and Intelligent Tutoring Systems on student learning, motivation or autonomy	

In the final phase, a further selection was carried out by focusing on the articles as a whole and only the articles available as full texts were included in the meta-analysis.

A confirmation phase of the bibliographic search was also performed on Science Direct, but the search returns the same results as the other databases.

The process described is shown in detail in Figure 1.

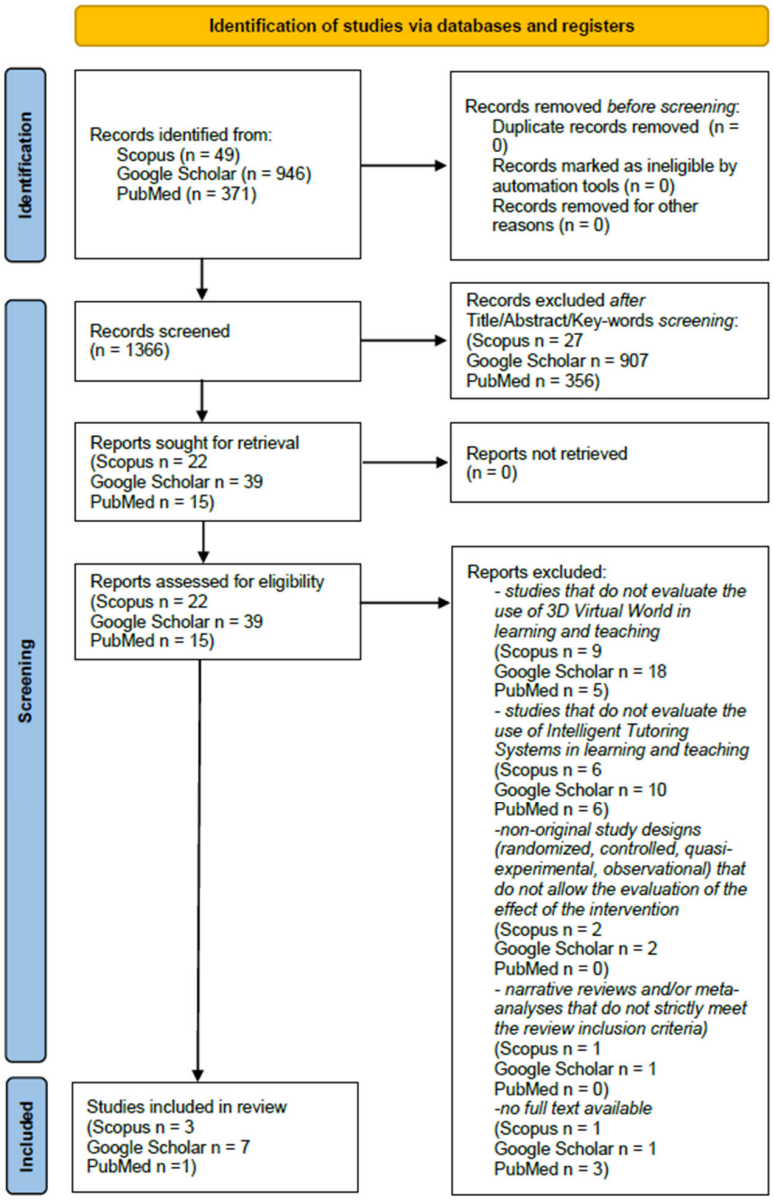


Figure 1. PRISMA 2020 Flowchart.

2.2. Quality and BIAS Evaluation

The methodological quality of studies was assessed using the Newcastle-Ottawa Scale (NOS). This tool evaluates studies in the following three domains: participant selection (maximum 4 stars), comparability of study groups (maximum 2 stars), and ascertainment of exposure or outcome (maximum 3 stars). Assessments were performed independently by two reviewers, and disagreements were resolved by consensus. Studies with a score of 7 to 9 stars were classified as high quality, those with a score of 5 to 6 stars as moderate quality, and those with a score of less than 5 stars as low quality. Table 2 details the studies included in this article and their NOS rating.

Table 2. Paper included in systematic literature review. Na, not assessed.

Author	Title	Journal	NOS Score
Occhioni et al. [2]	Environmental education in distance learning: using Virtual Worlds to link geosciences and sustainability	*Journal of Geoscience Education*, **2024**, *72*, 393–407	8
Damaševičius and Sidekerskienė [4]	Virtual Worlds for Learning in Metaverse: A Narrative Review	*Sustainability*, **2024**, *16*(5), 2032	Na
Grivokostopoulou et al. [18]	The Effectiveness of Embodied Pedagogical Agents and Their Impact on Students Learning in Virtual Worlds	*Applied Sciences*, **2020**, *10*(5), 1739	8
Filippone et al. [19]	Cooperative learning in virtual worlds: An innovative teaching and learning experience for STEAM education	*Italian Journal of Educational Research*, **2023**, (31), 100–113	8
Rohil et al. [20]	An architecture to intertwine augmented reality and intelligent tutoring systems: towards realizing technology-enabled enhanced learning	*Education and Information Technologies*, **2025**, *30*(3), 3279–3308	7
Kostadimas et al. [21]	A Systematic Review on the Combination of VR, IoT and AI Technologies, and Their Integration in Applications	*Future Internet*, **2025**, *17*(4), 163	Na
Diaz et al. [22]	Virtual world as a resource for hybrid education	*International Journal of Emerging Technologies in Learning*, **2020**, *15*(15), 94–109	7
Petrina and Zhao [23]	3D Virtual learning environment for acquisition of cultural competence: Experiences of instructional designers	In *Research Anthology on Virtual Environments and Building the Metaverse*, **2023**, pp. 675–701). IGI Global Scientific Publishing	7
Paris et al. [24]	Geoscience education using virtual worlds	*European Geologist*, **2020**, *50*, 39–44	8
Filippone et al. [25]	Virtual English LAB: The Impact of Virtual Worlds on English Language Learning and Life Skills in Higher Education	*Excellence and Innovation in Learning and Teaching-Open Access*, **2025**, *10*(1), 23–44	8
Filippone et al. [26]	Escape room in 3D virtual worlds: Reflections on new digital skills for innovative teaching by special educational teachers in training	*Italian Journal of Educational Technology*, **2025**, Accepted Manuscript Online	8

3. Results and Discussion

The search yielded 11 results that met the inclusion criteria (Table 2); details on the type of study conducted, the aim of this study, and the target sample studied are reported in Table 3, while details on the levels and methods of integration of these technologies into traditional teaching, the levels and methods of influence on study autonomy, and the relationship between these technological devices and social effects are reported in Table 4.

Table 3. Characterizing elements of the articles included in the systematic review (type of the study, objectives of the study, and sample-related target).

Author	Type of the Study	Objective of the Study	Sample-Related Target
Occhioni et al. [2]	Quasi-experimental	Environmental education with virtual worlds	School students in DAD (ages 13–18)
Damaševičius and Sidekerskienė [4]	Narrative Review	Theoretical analysis on the use of VWs in the metaverse	na
Grivokostopoulou et al. [18]	Experimental	Evaluating the effectiveness of pedagogical agents in VW	8

Table 3. *Cont.*

Author	Type of the Study	Objective of the Study	Sample-Related Target
Filippone et al. [19]	Quasi-experimental	Cooperative learning in virtual worlds	8
Rohil et al. [20]	Theoretical-design	Integrated AR + ITS architecture for enhanced learning	7
Kostadimas et al. [21]	Systematic review	Review of VR, IoT, and AI in the application field	na
Diaz et al. [22]	Longitudinal	Evaluating the use of VWs in hybrid education	7
Petrina and Zhao [23]	Qualitative and Descriptive	Analysis of the acquisition of cultural competence in 3D environments	7
Paris et al. [24]	Experimental	Geoscience Education with VW	8
Filippone et al. [25]	Quasi-Experimental	English language learning and life skills at VW	8
Filippone et al. [26]	Quasi-Experimental	Digital skills development and educational innovation through escape rooms at VW	8

Table 4. Characterizing elements of the articles included in the systematic review (integration into traditional teaching, methods of influence on study autonomy, and relationship about social effects).

Author	Integration into Traditional Teaching	Methods of Influence on Study Autonomy	Relationship About Social Effects
Occhioni et al. [2]	High level of integration VW integrated into distance learning on environmental topics	Moderate level of influence Promoting environmental problem solving	Positive effects on increasing sustainable awareness
Damaševičius and Sidekerskienė [4]	Theoretical integration Reflection on future scenarios	High level of influence (theoretical) VW as self-directed learning tools	Potential effects on promoting online collaboration
Grivokostopoulou et al. [18]	High level of integration VW with pedagogical agents simulate teacher interaction	High level of influence Individualized guidance through agents	Neutral effects on more individual focus
Filippone et al. [19]	High level of integration VW integrati in progetti STEAM scolastici	Moderate level of influence Guided cooperative learning	Positive effects on development of collaboration and inclusion
Rohil et al. [20]	Conceptual integration Architectural Proposal for ITS + AR	High level of influence (potential) Customization and adaptability	Potential effects on increased technological engagement
Kostadimas et al. [21]	Variable integration based on the cases examined	It depends on the technology integrated	Dependent on the context of use
Diaz et al. [22]	High level of integration VW integrated into blended courses	High level of influence Personal path management	Positive effects on interaction and peer-learning
Petrina and Zhao [23]	Medium level of integration experiences integrated into project paths	High level of influence Self-training on cultural competence	Positive effects on development of intercultural thinking
Paris et al. [24]	High level of integration 3D simulations as an extension of lessons	Moderate level of influence Guided activities in VW	Positive effects on active student engagement
Filippone et al. [25]	High level of integration VW in combinazione con lezioni in aula	High level of influence Autonomous exploration of the virtual world	Very positive effects on cooperative learning and peer-feedback
Filippone et al. [26]	High level of integration Educational escape room as an innovative tool	High level of influence Autonomous solution of complex problems	Very positive effects on collaboration and motivation

The 11 articles included in this systematic review, in order to highlight the pedagogical and technological focus of each contribution and to offer a more functional vision and favor a reasoned review, can be classified and grouped thematically as follows:

- Studies using 3D Virtual Worlds in education [2,4,19,21–26];
- Studies using Intelligent Tutoring Systems in education [20,21] (the latter as the subject of a systematic review);
- Studies using both systems [20,21] (it is necessary, however, to underline that none of them experiments both systems in an integrated way in the field, but the first one explores a theoretical integration between VR, IoT and ITS and the second one proposes a theoretical architecture between ITS, AR and VR);
- Studies aimed at enhancing learning outcomes [2,18,20–25];
- Studies aimed at enhancing motivation [4,19,22,23,25];
- Studies aimed at enhancing autonomy and self-regulation [4,18,21,22];
- Studies aimed at developing life skills [4,19,23,25];
- Studies aimed at developing digital skills [2,20,21,25,26].

The selection of scientific papers carried out through PRISMA analysis allowed us to identify a heterogeneous corpus of contributions, classifiable into four main methodological categories. Among these, two studies [18,24] can be considered truly experimental, as they were structured with control groups, pre- and post-tests, and quantitative learning assessments. Both investigated the effectiveness of integrating virtual environments on subject-specific learning, providing robust empirical evidence.

The largest group consists of quasi-experimental studies, which represent over half of the selected sample. These include the research by Filippone et al. [19,26], Occhioni et al. [2], and the Virtual English LAB study [25], all of which share structured educational interventions, albeit lacking rigorous randomization. These studies adopt pre-post designs, utilize validated questionnaires (e.g., MyDigiSkills, SUS, Cambridge scales), and analyze impacts on digital skills, motivation, life skills, and educational innovation. The presence of large samples (up to 840 participants) lends solidity to the exploratory and applicative value of these investigations.

A single contribution [22] falls into the category of longitudinal studies, monitoring students' learning and perceived development in hybrid environments over an extended period, with a three-phase timeline. This study stands out for its focus on ongoing educational transformation and the ongoing interaction between students and virtual environments.

Finally, two works constitute literature reviews. The systematic review by Kostadimas et al. [21] represents a point of reference for the convergence of VR, AI, and IoT in educational contexts, while the narrative review by Damaševičius and Sidekerskienė [4] provides a broad theoretical reflection on the evolution of virtual worlds in the metaverse. The other theoretical-design works [20,23] complete the picture, offering relevant insights on design, architecture, and digital culture, although they cannot be classified according to experimental or systematic criteria.

In summary, the emerging landscape reflects the vitality of the field of educational research on virtual worlds, with a predominance of quasi-experimental approaches and a growing focus on design and methodological aspects. This body of research provides a solid starting point for further comparative investigations, meta-analyses, and longitudinal studies aimed at evaluating the effectiveness and educational sustainability of virtual environments in contemporary education.

3.1. Virtual Worlds and Intelligent Tutoring Systems as Tools for Educational Innovation and Learning Support

The literature analyzed confirms a growing interest in the use of Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) as innovative tools for teaching and they have established themselves as powerful instruments to promote interactive, exploratory and student-centered learning [19]. In particular, several studies [19,22,24–26] document how Virtual Worlds can support student-centered teaching practices, offering immersive environments for cooperative, laboratory-based and personalized learning. These digital environments provide a simulated space where learners can engage with complex problems, develop practical skills, and participate in dynamic educational experiences. By extending beyond traditional classrooms, Virtual Worlds integrate seamlessly into hybrid and mobile learning settings, offering immersive interactions that enhance student engagement and knowledge retention [27].

One of the defining characteristics of Virtual Worlds in education is their high level of interactivity and embodiment [3]. Through avatar-based interactions, students actively participate in digital learning experiences, moving beyond passive content consumption. The persistent nature of these environments allows for asynchronous collaboration, enabling learners to continue their engagement even when offline. Moreover, Virtual Worlds can integrate with existing Learning Management Systems (LMS), such as Moodle and OpenSimulator, creating a blended learning experience that bridges traditional and digital education.

The educational benefits of Virtual Worlds are substantial. Immersive learning environments improve comprehension and retention of complex concepts through three-dimensional visualization. Their collaborative potential fosters peer-to-peer learning and real-time communication, making them valuable for teamwork-oriented disciplines. Additionally, these environments support exploratory learning by providing a safe space for experimentation, which is particularly beneficial in fields such as medicine, engineering, and environmental sciences [2,28–30].

At the same time, studies such as those by Rohil et al. [20] and Kostadimas et al. [21] highlight the potential of ITS in providing individualized support, real-time feedback, and adaptive learning paths, thanks to the power of artificial intelligence.

However, although both tools are recognized for their effectiveness, few studies truly integrate VW and ITS into a single educational ecosystem. This highlights a methodological gap and a possible future direction for educational research: the design of immersive environments that, in addition to offering three-dimensional experiences, also integrate intelligent tutors capable of monitoring and guiding the learning process.

From this perspective, it is, also, essential to clarify that the introduction of technologies such as Virtual Worlds and Intelligent Tutoring Systems should not be interpreted as an attempt to replace the role of the teacher, but rather as an opportunity to integrate and amplify his/her skills. Their implementation must take place within a conscious methodological framework, which preserves the relational and intentional dimension of the educational process. The immersive and personalizing potential of VW-ITS can generate highly engaging learning environments, but their value emerges fully only if combined with educational practices that place interaction, metacognitive reflection and adult training support at the center. The educational implications, therefore, concern the need to rethink the spaces and times of teaching, promoting hybrid models in which technology is at the service of authentic, collaborative and student-centered learning [1,31].

Despite these advantages, challenges remain in integrating Virtual Worlds into mainstream education. Issues such as cognitive overload, navigation complexity, and accessibility barriers can hinder student engagement, especially for learners with limited prior

exposure to digital technologies. Furthermore, the lack of structured guidance within these environments necessitates the development of adaptive mechanisms to personalize learning experiences and support individual needs [31].

Overall, while Virtual Worlds hold great promise for transforming education, their effective implementation requires careful consideration of their limitations [28]. Addressing accessibility issues, refining instructional design, and enhancing integration with adaptive learning technologies will be key to maximizing their educational impact.

3.2. Adaptive Features of 3D Virtual Worlds and Their Potential Use as Tutoring Systems

A second line of reflection concerns the adaptive characteristics of Virtual Worlds built on a constructivist basis and their potential configuration as tutoring systems.

It is important to highlight how Intelligent Tutoring Systems (ITS) and Virtual Adaptive Tutoring Systems (ATS) are transforming traditional learning environments by leveraging artificial intelligence to personalize instruction. These systems dynamically adjust pedagogical strategies, feedback mechanisms, and content difficulty based on learners' cognitive profiles, fostering greater autonomy and efficiency in the learning process [1].

A defining feature of ITS is adaptive feedback, which analyzes student performance and engagement patterns to provide real-time, customized guidance. These systems also incorporate behavioral analytics, monitoring learner interactions to refine content delivery and optimize teaching strategies. Additionally, pedagogical flexibility allows ITS to support various learning approaches, including constructivist, cognitivist, and behaviorist models, ensuring that students receive instruction aligned with their cognitive and learning preferences.

The potential configuration of the adaptive characteristics of Virtual Worlds built on a constructivist basis as tutoring systems is fully supported by the works of Grivokostopoulou et al. [18] and Filippone et al. [25] who offer interesting evidence in this sense: the first explores the use of embodied pedagogical agents to guide students within the virtual world, while the second experiments with an environment in which the personalization of the experience and exploratory freedom are combined with structured tasks and moments of metacognitive reflection. Diaz et al. [22] and Occhioni et al. [2] also underline the possibility of designing VWs that adapt to the rhythms and learning styles of students, stimulating autonomy and motivation.

Although not yet fully fledged ITS, these environments are beginning to exhibit tutor-oriented characteristics, such as implicit progress monitoring, situated feedback, and the ability to act as "digital mentors" within an immersive context. Theoretical reviews [4,21] confirm this perspective, calling for greater convergence between adaptive learning models and the affordances of 3D worlds in the metaverse.

Incorporating adaptive learning mechanisms into 3D Virtual Learning Environments (3D-VLEs) has shown promising results in enhancing engagement while mitigating risks of cognitive overload and distraction [31]. By integrating real-time feedback based on artificial intelligence, these systems can address gaps in self-regulated learning, offering targeted interventions when needed. Furthermore, automated assessment capabilities would allow these new tutoring systems to identify struggling students and adapt content delivery accordingly, ensuring a more personalized and effective learning experience.

Despite their effectiveness, tutoring systems, as so intended, limiting the exploratory nature that characterizes immersive learning in Virtual Worlds [32]. Researchers are now exploring ways to merge these technologies, aiming to integrate the structured support of ITS with the engagement and interactivity of Virtual Worlds. This hybrid approach seeks to maximize the benefits of both systems, creating a more dynamic and personalized learning environment that enhances both structured guidance and exploratory learning.

3.3. Towards Adaptive Learning in the Metaverse: Integrating VW and ITS as a Frontier of Educational Innovation

The third objective of this study aimed to investigate whether Virtual Worlds can serve as valid educational devices for adaptive learning, especially when combined with ITS within a metaverse ecosystem.

The selected literature shows promising signs. The works of Filippone et al. [26] and Petrina and Zhao [23] present immersive environments that foster engagement, critical thinking, and the development of transversal skills, contributing to creating a deeply personalized and motivating educational experience. Although none of the reviewed studies describe a full integration between ITS and VW in a metaversal environment, the interest in adaptive learning models that combine immersion, real-time data analysis, and educational personalization clearly emerges. In particular, the article by Rohil et al. [20] offers a theoretical model of an integrated architecture between AR, VR, and ITS that could be applied to educational settings, while that of Kostadimas et al. [21] proposes a systematic review of IoT- and AI-based applications already in use in educational contexts. According to these studies, the future of digital teaching will therefore involve the synthesis of immersive virtuality, intelligent tutoring, and real-time adaptability, capable of responding to the diverse needs of students within the Metaverse.

The integration of Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) represents, therefore, a significant advancement in educational technology, leveraging the strengths of both systems to create adaptive, engaging, and student-centered learning experiences. Virtual Worlds provide immersive, interactive spaces that facilitate experiential learning, while ITS offer personalized, data-driven instruction tailored to individual learner needs [33]. Their combined use can enhance learning effectiveness by addressing the limitations of each system, fostering a more dynamic and responsive educational environment.

Both Virtual Worlds and Intelligent Tutoring Systems share key characteristics that contribute to effective learning. Personalization and adaptability are central to both, as they dynamically adjust instructional content based on learner progress. Virtual Worlds sustain engagement and immersion through interactive simulations, while ITS enhance motivation by providing individualized learning pathways [1,4]. Additionally, both systems support collaborative and social learning, with Virtual Worlds enabling peer-to-peer interaction and ITS enriching these experiences through AI-driven coaching and structured interventions.

The integration of ITS within Virtual Worlds introduces new opportunities for enhancing learning. Real-time AI-driven content adaptation allows immersive simulations to adjust dynamically to learner needs, making instruction more responsive. Furthermore, scalable, data-driven learning analytics refine teaching methodologies by providing continuous insights into student performance. The combination of gamification elements—such as leaderboards, adaptive challenges, and rewards—with ITS personalization strategies enhances motivation and retention, ensuring a sustained engagement with the learning process [34].

This synergy also fosters personalized and adaptive learning. ITS can analyze learner interactions within a Virtual World and modify tasks, challenges, or scenarios in real time to align with their proficiency level. AI-driven tutoring agents embedded in these environments provide contextual feedback, improving comprehension and knowledge retention. Additionally, Virtual Worlds' ability to naturally integrate gamified elements further strengthens motivation, creating a learning loop where real-time actions and decisions shape the educational experience [18].

In terms of collaborative learning, Virtual Worlds offer social interaction through avatar-based engagement, enabling group problem-solving tasks that can be guided by

ITS algorithms. AI-driven tracking of group dynamics ensures that collaboration remains effective, with intelligent interventions supporting productive peer interactions.

From a technical point of view, the integration between Virtual Worlds and Intelligent Tutoring Systems involves significant challenges related to real-time synchronization between user interactions, AI adaptivity and graphic rendering. Some studies [20,21] have shown that the adoption of modular architectures, in which the virtual environment engine is separated from the adaptive module but interconnected via APIs, allows for greater flexibility and scalability. Furthermore, systems based on interoperable web technologies, such as WebXR for immersive representation and predictive models powered by distributed machine learning, allow for real-time data analysis without overloading the client. A promising technical framework is that of adaptive middleware, which dynamically manages the flows between interface, engine and AI modules, ensuring a balance between computational performance and educational personalization. These solutions, if accompanied by standardized and open-source tracking protocols, can favor a wider and more efficient diffusion of VW–ITS.

Despite these advantages, technical challenges persist. The integration of AI into Virtual Worlds requires significant computational power, and ethical considerations such as data privacy and AI bias must be addressed. Researchers emphasize the need for phenomenological toolkits to structure metaverse-based learning experiences, ensuring accessibility, ethical AI deployment, and effective cognitive scaffolding.

The convergence of Virtual Worlds and Intelligent Tutoring Systems holds immense potential for shaping the future of education [31]. By combining the structured, adaptive nature of ITS with the immersive, interactive elements of Virtual Worlds, this hybrid approach creates a highly personalized and engaging learning environment. However, successful implementation will require addressing technical and ethical challenges to ensure equitable, effective, and scalable educational solutions [22].

Finally, it is important to underline that in order for the integration of VW and ITS to be rigorously assessed, it is necessary to develop measurement frameworks that are consistent with the specific educational purposes of the different application contexts. The literature, as suggested by Fontaine et al. [8], shows that the impact of such technologies can be analyzed in terms of knowledge retention, transfer of skills in authentic contexts, improvement of academic results and development of transversal skills such as collaboration and problem solving. A systematic approach should include quantitative indicators (standardized tests, objective performance assessments) and qualitative indicators (observations, rubrics, self-assessments and feedback). Furthermore, learning analytics tracking models already applied in adaptive environments [1] can be integrated to monitor the process as well as the product of learning. Future research should therefore focus on the construction of mixed-method evaluation models capable of capturing both the cognitive and socio-emotional aspects of learning outcomes, also from a longitudinal perspective.

3.4. Case Studies and Applications

The integration of Virtual Worlds with Intelligent Tutoring Systems (ITS) has proven effective across various educational domains, enhancing both engagement and learning outcomes. These environments provide immersive, interactive spaces where learners can develop practical skills in a controlled and adaptive setting [35].

One of the most impactful applications is in medical training, where Virtual Worlds simulate surgeries and diagnostic procedures, allowing students to practice critical tasks without real-world consequences. ITS embedded within these environments assess learner performance, provide real-time feedback, and guide students through complex medi-

cal scenarios. This ensures that trainees can refine their skills in a risk-free, yet highly realistic, setting.

In STEM education, disciplines such as physics and engineering benefit significantly from 3D simulations that bring abstract concepts to life. Virtual Worlds enable students to explore scientific phenomena dynamically, while ITS support these experiences by offering structured guidance, breaking down complex problems, and providing adaptive assessments. This combination, especially in middle school students, has been shown to foster deeper conceptual understanding and practical application [2,19].

Similarly, language learning has been transformed through Virtual Worlds that offer immersive linguistic environments, as found in studies involving both middle school and university students [19,25,36]. Students can engage in real-time conversations, practice pronunciation, and refine their grammar in interactive simulations. ITS play a crucial role in monitoring speech patterns, detecting errors, and providing personalized feedback, allowing learners to improve fluency and accuracy through AI-driven corrections and suggestions [37].

These applications highlight the potential of combining Virtual Worlds and ITS to create dynamic, student-centered learning experiences. By leveraging immersive simulations with adaptive feedback, educators can enhance engagement, foster skill development, and provide personalized learning paths tailored to individual needs [38].

4. Pedagogical Reflections, Limitations, Challenges and Future Directions

While Virtual Worlds integrated with Intelligent Tutoring Systems (ITS) offer significant potential for enhancing education, several challenges must be addressed to ensure their widespread adoption and effectiveness. These challenges span technological, pedagogical, and ethical domains, requiring interdisciplinary solutions to create sustainable and scalable learning environments [8].

4.1. Emerging Technologies and Basic Educational Principles: A Necessary Balance

With reference to the integration of immersive technologies such as virtual worlds (VW) and intelligent tutoring systems (ITS), a latent risk of imbalance between technological enthusiasm and the need to maintain fundamental pedagogical principles is detected. This is why it should be conceived as a strategy to improve traditional educational principles, not as a replacement for them. Educational technologies, however promising, cannot replace educational action based on relationships, formative intentionality and the shared construction of knowledge [4]. The literature examined demonstrates that these technologies, if used with awareness, can support active, collaborative and personalized learning [4,19].

However, the risk of excessive technological dependence, if not balanced by intentional pedagogical planning, is real [39]. It is therefore necessary to support fundamental educational values, such as meaningful interaction between teacher and student, the authenticity of the learning experience and the centrality of relationships, to prevent the efficiency of technology from obscuring the profound meaning of education [40]. It is therefore necessary to consider these new technologies as tools to enhance human-centered teaching, through a planning that values the active role of the teacher as a facilitator of meaning [41,42].

4.2. From Substitution to Integration: A Hybrid Model for the School of the Future

Most of the studies analyzed highlight the potential of VW-ITS in supporting hybrid and adaptive learning environments, but a clear definition of integration models with traditional teaching is often lacking. Significant experiences with blended teaching show that the joint use of virtual environments and in-person moments can foster engage-

ment and personalization, but the transition to transformative teaching requires careful pedagogical mediation. Filippone et al. [19] propose a cooperative framework in which virtual experiences are intertwined with moments of collaborative work in person. Similarly, Díaz et al. [22] highlight how the use of VW fosters mixed environments capable of enriching traditional teaching.

However, integration often remains implicit. Only a few studies offer operational frameworks for the intentional inclusion of these technologies in existing curricula [20]. Therefore, a deeper reflection on the interaction between consolidated practices and new technological affordances is desirable, through an integrated pedagogical approach based on the principle of complementarity [43].

4.3. Autonomy and Dependence: Promoting Critical Thinking and Metacognition

Although VW-ITS are often presented as tools for personalized learning, the risk of inducing cognitive dependence is significant, with the risk that interaction with intelligent systems leads to student passivization. However, some evidence [18] shows how intelligent pedagogical agents can promote self-reflection and critical thinking when integrated into scenarios that enhance metacognition.

Furthermore, virtual environments such as the English LAB [25] are designed to offer spaces for autonomous exploration, where students can choose their own paths, tools and strategies. As Zimmerman [44] underlines, self-regulation is a skill that can be trained, but requires stimulating and non-simplified environments. The intelligent use of VW-ITS should therefore enable autonomy, not replace it, and what has been analyzed through the exploration of the studies identified in the literature review allows us to understand how this is the path to follow and the one on which to continue investigating in order to fill the current gap and not weaken students' critical thinking, but rather strengthen it, thus making the new technological strategy a scaffolding for traditional teaching.

4.4. Children and Adolescents: Adapting Technologies to Cognitive and Emotional Development

An obvious limitation of the literature is the paucity of applications targeted at K-12 contexts. Most studies focus on university students [23,25], while use with children and adolescents is less explored, although the literature review highlighted applied studies on middle school students, which shows that this is a path on which new studies are focusing in this direction [19]. However, it is known that childhood and adolescence require differentiated approaches, in which learning proceeds through discovery, play, and error [14].

As highlighted by Choi-Lundberg et al. [45], adaptive learning in the early stages must be mediated by significant adults and by technologies designed to stimulate, not replace, emerging cognitive functions. The pedagogical challenge is therefore to scaffold the use of smart technologies, adapting them to children's neurocognitive and affective development. Considering the results obtained in studies conducted on middle school students [2,19], it is possible to hypothesize how VW-ITS interaction can promote, even in the K-12 context, an adaptation of contents, languages and interaction methods, so that the digital experience does not reduce the complexity of learning but makes it accessible and meaningful [14,46,47].

4.5. Social Learning, Emotional Intelligence, and Authentic Relationships

Many studies consider the collaborative dimension as a strong point of virtual worlds, and although some studies cite collaboration and the social dimension of learning [4,25], few delve into their effect on socio-emotional development and the impact of these technologies on the development of emotional intelligence, interpersonal skills and intercultural awareness. Yet, social interaction is central to educational processes, especially during de-

velopmental age. Virtual worlds, however, can offer opportunities for intercultural and simulated interaction, as in the case of environments oriented towards cultural competence [23], but they cannot replace the empathic and embodied relationships typical of school in the real world, especially in the processes of identity growth and emotional literacy.

As Dede [48] and Immordino-Yang et al. [49] point out, deep learning is rooted in emotions and relationships. It is therefore necessary that VW-ITS are also designed to train emotional intelligence, through meaningful interactions and authentic collaborations, not only through avatars or simulated agents. The analysis of this literature review therefore offers interesting ideas for continuing research in this direction, in favor of studies that, in addition to the cognitive and procedural dimensions, delve into the implications for the strengthening of a healthy identity growth, a concrete emotional literacy also through the development and strengthening of life-skills, as some studies are beginning to investigate [25].

4.6. Ethics, Privacy, and Algorithmic Justice in Digital Education

Finally, a critical issue concerns the ethical implications of using VW-ITS, particularly regarding privacy, consent, access, and algorithmic bias. The article by Kostadimas et al. [21] draws attention to the risks associated with the integration of VR, AI, and IoT, highlighting how unregulated use can undermine educational equity.

In K-12 contexts, these concerns are amplified: children are not fully able to understand the implications of data collection or learning mediated by predictive algorithms [50]. It is therefore urgent to develop an ethics of digital instructional design that protects the most vulnerable and promotes transparency, inclusion, and algorithmic justice. Careful reflection in this sense is necessary for the implementation of future studies, to reverse what the lack of transparency towards automated decision-making processes may imply in terms of compromising the right to personalized and inclusive education. Future lines of research and development must therefore include ethical, legal, and pedagogical dimensions, promoting an educational governance of innovation that places the protection and growth of the individual at its core. Only in this way will it be possible to use these technologies responsibly, placing human development at the center.

4.7. Limitations of the Study

Limitations of the present study include the low number of outcomes analyzed and the exclusion criteria.

Another limitation may arise from the general nature of systematic literature reviews in general, regarding the restriction of included studies, particularly in cases where studies present divergent quality standards (e.g., inadequate experimental design, limited sample size, and type of participant targeting, which may impede the generalizability of the conclusions). The authors are aware of these limitations and intend to continue this research to gather more data and evidence.

5. Conclusions

The integration of Virtual Worlds (VW) and Intelligent Tutoring Systems (ITS) represents a significant advancement in digital education, offering a hybrid approach that combines immersive, interactive learning with personalized, AI-driven tutoring. This study has explored the synergies between these technologies, highlighting their ability to enhance engagement, facilitate experiential learning, and adapt to individual student needs through dynamic instructional strategies.

The findings demonstrate that VW and ITS share key features such as personalization, adaptability, and real-time feedback, making them complementary tools in modern educa-

tion. Their combined use has been successfully applied in fields such as medical training, STEM education, and language learning, both in university context, among trainees and students, and in middle school, where adaptive learning models provide targeted guidance while maintaining an exploratory and engaging learning environment. Virtual Worlds foster collaboration and problem-solving, while ITS refine content delivery and ensure that learners receive structured support.

Despite these advantages, several challenges must be addressed for widespread adoption. The technological barriers related to computational power, AI integration, and real-time data processing require robust infrastructure and cloud-based solutions. The pedagogical challenges of balancing structured learning with the open-ended nature of Virtual Worlds highlight the need for carefully designed instructional frameworks to prevent cognitive overload. Additionally, ethical considerations surrounding data privacy, algorithmic bias, and transparent AI decision-making must be prioritized to ensure fair and secure learning experiences.

Future research should focus on the development of hybrid models that leverage emerging technologies such as blockchain for secure data management, IoT-based real-time analytics for enhanced learner engagement, and augmented reality to bridge virtual and physical learning environments [4,51]. By addressing these challenges, Virtual Worlds and Intelligent Tutoring Systems can be further optimized to create scalable, adaptive, and inclusive educational experiences [31].

In conclusion, while the convergence of VW and ITS holds immense potential for transforming education, its success depends on technical innovation, instructional design improvements, and ethical AI governance [52]. A concerted effort from researchers, educators, and policymakers will be required to fully harness the capabilities of these technologies and shape the future of personalized, immersive learning.

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