Teaching and Learning in 3D Virtual Worlds integrated with Intelligent Tutoring Systems: New perpectives for Virtual Reality, Eduverse and Artificial Intelligence in Education

Alfonso Filippone[*^], *Umberto Barbieri*[**], *Emanuele Marsico*[***], *Maria Ermelinda De Carlo*[****], *Raffaele Di Fuccio*[*****]

Abstract

Digital Transformation in Education increasingly provides innovative and effective opportunities to reshape traditional educational paradigms, supporting complex ecological systems and promoting a teaching approach that effectively responds and adapts to students' educational needs.
This paper illustrates possible challenges and future perspectives for Virtual Reality, Eduverse and Artificial Intelligence in Education through the implementation of 3D Virtual Worlds integrated with Intelligent Tutoring Systems as learning tools to promote sustainability education. These educational tools may represent a new educational paradigm capable of promoting teaching and learning processes, acting on motivation, enhancing digital soft skills and life skills, and improving learning outcomes from the perspective of adaptive learning.

[*] PhD student in Digital Transformation (curriculum Education), Department of Psychology and Education, Pegaso University, Italy, and Contract Professor at DAFNE, DISTUM and Medical Area Departments, University of Foggia, Italy.
[**] PhD student in Digital Transformation (curriculum Education), Department of Psychology and Education, Pegaso University, Italy.
[***] PhD student in Learning Science and Digital Technologies, Department of Psychology and Education, Pegaso University, Italy.
[****] RTD-B in Experimental Pedagogy, Department of Psychology and Education, Pegaso University, Italy.
[*****] Associate Professor in Teaching and Special Pedagogy, Department of Psychology and Education, Pegaso University, Italy.
[^] Corresponding author: alfonso.filippone@unipegaso.it.
The article is the result of discussion and scientif collaboration among the authors. However, the attribution of scientific responsibility is as follows: A. Filippone, paragraphs 1 and 3, as well as the supervision of the article; U. Barbieri and M. Marsico, paragraph 2; M.E. De Carlo and R. Di Fuccio, paragraph 4.

Doi: 10.3280/ess2-2024oa18448

Key words: 3D Virtual Worlds; Eduverse; Artificial Intellingence; Innovative Teaching and Learning Methods; Intelligent Tutoring Systems; Adaptive Learning.

First submission: 10/09/2024, accepted: 12/12/2024

1. 3D Virtual Worlds as Learning Environments

According to de Freitas (2008) a Virtual World is an online, persistent, interactive environment accessible by many users simultaneously.

The origin of virtual worlds lies in the first implementation of text-based role playing games in the 1979 (Pannicke and Zarnekow, 2009) when the first multi-user dungeon (MUD) was programmed (Bartle, 2003).

The content of virtual game worlds has always been linked to literature and especially inspired by science fiction and medieval fantasy genres. The main character, represented by an avatar, had the task of achieving objectives that were the basis of the game.

Thanks to the spread of the Internet, these computer games became available beyond the frontiers of university networks and, considering the continuous evolution of digital technology, which has taken on a fundamental role in the field of education, supporting and innovating traditional teaching, virtual worlds can represent a technology available to educators for teaching and learning (Kelton, 2008).

It is important to point out that in the literature on educational research there are many terms that serve to identify this new form of technology that on the one hand illustrates the different typologies and on the other generates a fragmented understanding of the development of virtual worlds both on the basis of technical and experiential characteristics.

Among the various terminologies present in literature we can mention: virtual wolrd (VW), virtual environment (VE), multi-user virtual environment (MUVE), massively-multiplayer online (role-playing) game (MMO(RP)G), immersive virtual world (IVW), immersive world, immersive online environment, 3D virtual learning environment, open-ended virtual wolrds, simulated worlds, serious virtual world, social virtual world, synthetic virtual world and virtual learning environment (VLE) (Girvan, 2018).

In order to avoid confusion through conceptual misunderstandings, in this article we will refer to 3D Virtual Learning Environments (3DVLE), in fact, considering the continuous and incessant developments in information and communication technologies that have significantly influenced learning processes, and the innovations in the field of education that have outlined a vital importance for learning applications (McGee, 2007; Robben, 2007), a surprising innovation in this sense is precisely the development of three-dimensional (3D) virtual world platforms that over the years have been used to create innovative teaching and learning approches.

Differently from the virtual world, a 3D Virtual World can be considered as a synchronous, persistent network of people, represented as avatars, facilitated by network computer (Bell, 2008).

Nowdays 3D Virtual Worlds are being considered as a potential medium to provide learners with new educational environments (Dass et al., 2010; de Freitas et al., 2010; Delwiche, 2006; Jarmon et al., 2009).

In the 3D Learning Virtual Worlds users can access simultaneously within the same virtual space and are represented in this new media context as avatars. They can communicate, exchange data using text chats or real voice systems.

In recent years, the literature has been enriched by numerous studies that have focused attention on the use of 3D Virtual Worlds as virtual environments in which to allow the delicate teaching-learning binomial to come to life and to be innovated and enhanced so as to allow teachers and students to co-construct new knowledge together to promote increasingly significant learning (Filippone et al., 2023; Bevilacqua and Filippone, 2023; Occhioni, 2017; Occhioni et al., 2023; Paris et al., 2020; Panconesi and Guida, 2017).

These new Virtual Learning Environments, generally built and implemented using completely free online platforms, allow teachers and students easy access and simple use.

In this way, teachers can enrich virtual environments with structured disciplinary and multidisciplinary teaching paths, integrating interactive activities created with the most varied free teaching software available on the market and generally used in digital teaching especially after the recent pandemic period.

Teachers and students can meet virtually and benefit from innovative teaching methods that are highly flexible, engaging, stimulating, and fully responsive to new trends in the educational field, supporting ordinary teaching methods so as to combine innovation with already consolidated teaching methods (Filippone et al., 2023).

Study materials, exercises, reinforcement and enhancement possibilities can thus always be accessible to students, adapting to the needs of each individual, respecting the different times and learning styles and personalising teaching also in view of the different types of Special Educational Needs, in fact accessibility and usability are the basis of the preparation of this new media space to support students with disabilities.

In fact, learning environments structured in this way are easily accessible thanks to the use of PCs, tablets, smartphones, Chromebooks or through immersive experiences (Metaverse).

From this latter perspective, virtual worlds can represent immersive environments that allow for situated and constructivist learning, in which the student is inside a computer-simulated environment. Here, activities and experiences can take place using different didactic approaches, engaging the students and enhancing the learning process (Paris et al., 2020).

Learning in Metaverse allows students to live an experience that merges physical reality with digital virtuality. Through the use of cutting-edge technologies, students can enjoy multisensory interactions with virtual environments, digital objects and people such as virtual reality (VR) and augmented reality (AR). Therefore, Metaverse can be considered as an interconnected network of immersive social and networked environments in persistent multi-user platforms (Mystakidis, 2022).

Learning in the Metaverse, also, fosters seamless, real-time, embodied user communication and dynamic interactions with digital artifacts (Damaševičius and Sidekerskienė, 2024).

2. Adaptive Learning and Intelligent Tutoring Systems

The effectiveness of actively involving the student in the learning process is the basis of a learner-centered teaching model that promotes and facilitates the development of transversal skills such as critical thinking, problem solving skills and autonomy in learning (Quaicoe et al., 2023).

Personalized methodologies, based on the student's preferences or idiosyncrasies (Xie et al., 2019), are those capable of adapting to the cognitive, affective and intra-individual specificities of each student and are the most effective teaching strategies in terms of learning, motivation and involvement (Taylor et al., 2021).

Similar 3D learning virtual worlds, constructivism serves as a fundamental theoretical paradigm in modern pedagogy, emphasizing the active role of students in constructing their own knowledge and fostering their cognitive empowerment. (Merikko and Kivimaki, 2022). Furthermore, constructivist thinking considers the entire learning process as dynamic and interactive, considering the student as a subject capable of actively processing information, connecting it to his/her previous experiences to construct new meanings (Krahenbuhl, 2016).

The effective implementation of such an approach requires technologies capable of facilitating the active involvement of the student and of adapting to his/her specific characteristics, avoiding a standardized approach to teaching.

Personalized learning can be supported by educational technologies that provide flexible and interactive tools that allow students to progress at their own pace and receive immediate feedback.

Adaptive Learning (AL) presents itself as an effective solution to promote personalized learning in this perspective and stands out for its ability to personalize the learning process through the detailed analysis of student performance and responses, generating feedback and customized educational content during interaction with the learner (Adamu et al., 2019). Specifically, AL systems collect real-time data on student performance, analyzing behavior patterns, learning styles, and gaps in understanding (Abyaa et al., 2019).

The information obtained is processed by AL algorithms that dynamically adapt the presentation of content, the difficulty level of activities and the type of support provided, in order to optimize the learning experience for each individual student (Kolchenko, 2018) while also making real-time adjustments to maximize the effectiveness of individual study and implement interventions aimed at enhancing educational and academic success (Mikić et al., 2022).

Systems like the one illustrated are able to identify the areas in which the student encounters greater difficulties, providing additional explanations, practical examples or targeted reinforcement exercises, also promoting student motivation and engagement, proposing challenges appropriate to their level of competence and providing positive and encouraging feedback (Taylor et al., 2021).

AL, therefore, can be considered as an innovative technology capable of combining the constructivist paradigm with sophisticated analysis techniques, allowing the learning process to be verticalized and one's analyses to be guided according to a consolidated theoretical model.

An AL environment must satisfy four fundamental principles:

- continuous monitoring of user interactions;
- analysis and interpretation of such interactions according to theoretical models specific to the context;
- deduction of the needs and peculiarities of the users starting from the interpreted activities;
- dynamic modulation of the knowledge construction process, exploiting the information acquired on the users and on the didactic content.

Although scientific literature highlights the effectiveness of individualized instruction in promoting student learning, the large-scale implementation of adaptive teaching requires the intervention of advanced technologies, which have not yet been fully available (Penarrubia-Lonzao et al., 2021) such as

Intelligent Tutoring Systems (ITS), which appear to be a promising solution, embodying the intersection between computer science and educational neuroscience (Dermeval et al., 2018).

ITS rely on artificial intelligence algorithms for the dynamic processing of student responses and the progressive adaptation of teaching strategies, in order to meet individual needs (Kulik and Fletcher, 2016).

Based on this information, ITS dynamically adapt the presentation of content, the level of activities and the type of support provided, optimising the learning experience for each individual student.

The adaptation of teaching strategies occurs according to an interactive process of personalized learning, in which the system constantly monitors the student's performance and makes changes in real time to maximize the effectiveness of the instruction (Dermeval et al., 2018).

ITS can provide immediate suggestions, additional explanations, practical examples or targeted reinforcement exercises, based on the specific needs of each student and are based on three main components: the student model, the domain model and the teaching model (Al-Bastami and Naser, 2017).

The learner model uses advanced data mining and machine learning techniques to build a detailed profile of the learner, analyzing their interactions with the system, performance, gaps in understanding, and learning preferences. This information is used to personalize the learning experience and dynamically adapt instructional strategies.

The domain model, on the other hand, deals with structuring the content to be taught in a logically coherent and pedagogically valid way, incorporating elements of knowledge ontology (Nkambou et al., 2023). This model organizes knowledge in a hierarchical way, identifying key concepts, the relationships between them and the prerequisites necessary for understanding each topic. A well-structured representation of the knowledge domain is essential to ensure that the learning material is presented in a gradual and coherent manner, promoting the acquisition of a deep understanding by the students.

Finally, the teaching model uses algorithms to determine the most effective method and pace for presenting the learning material, based on continuous feedback provided by the student model. This model incorporates several pedagogical strategies, such as inquiry-based learning, Socratic tutoring, and scaffolding support, adapting them to the individual needs of students. The main aim is to optimize the learning experience by providing the right level of challenge and support to keep students engaged and motivated.

On a technical level, ITS integrate advanced Natural Language Processing (NLP) systems to interpret student interactions, enabling more natural and intuitive communication between the learner and the system (Agustianto et al., 2016).

To support these advanced capabilities, ITS require a robust and scalable software infrastructure that can handle real-time interaction and data analysis, which involves the use of distributed architectures, high-performance databases, and cloud computing technologies to ensure system availability, reliability, and scalability. However, the greatest challenge in designing effective ITS lies in the harmonious integration of these complex components into a system that is not only technically advanced, but also pedagogically grounded in solid theoretical and empirical foundations (González-Brenes and Mostow, 2012).

It is essential that the development of ITS is guided by well-established pedagogical principles and a thorough understanding of learning processes, in order to ensure that these systems are able to promote the acquisition of knowledge and skills in an effective and efficient manner.

Therefore, ITS represents a multidisciplinary research area that combines computer science, educational neuroscience and pedagogy to create adaptive and personalized learning systems.

3. Adaptive 3D Intelligent Virtual Learning Environments: new opportunities for Digital Transformation in Education

To ensure educational and academic success, it becomes necessary to personalize learning as much as possible, meeting the inclinations and propensities of students, their characteristics in times of pace and learning styles.

The widespread use of new digital technologies in the field of education has led teachers and educators to increase the use of virtual learning environments, obtaining truly promising results in terms of learning outcomes and motivation to learn.

Furthermore, new 3D technologies, taking into account the individual needs and preferences of students, have increasingly favored personalized learning approaches that required the adaptation of learning environments to the student, now completely at the center of the educational process.

Literature reports that numerous studies have focused, in recent years, on AL experiences in 3D Virtual Learning Environments although it is not yet possible to evaluate with certainty which evaluation factors may be involved in the recorded learning benefits (Scott et al., 2016).

Adaptive approaches have been included by many VLEs taking advantage of the educational systems (Shute and Zapata-Rivera, 2012) (Park and Lee, 2003) and the different services needed to achieve adaptation, such as student context (Knutov et al., 2009), performance assessment (Biletska et al., 2010) and feelings assessment (DMello et al., 2012).

Recent studies have also highlighted the importance of the Metaverse in education.

These type of Virtual World is primarily used for education, such as virtual classrooms, training simulations, and virtual labs (Kye et al., 2021).

Educational metaverse environments also allow users to collaborate on projects, discuss and share idea, access resources from around the world and interact in a virtual setting (Akour et al., 2022).

While educational metaverse have the potential to create a new and more dynamic learning environment, they require a certain level of oversight to ensure they are safe and secure for students and educatore alike.

The use of Metaverse for teaching and learning has gained increasing attention in recent years as virtual and augumented reality technologies have become more widely available (Lee et al., 2022; Tian, 2022).

Several studies have investigated the potential of the Metaverse for education and identified a range of advantages and challenges associated with its use (Akour et al., 2022; Diaz et al., 2020; Park and Kim, 2022).

It's worth noting that the technology of Metaverse is relatively new, and it's not yet widely adopted in most countries, including several developing countries and emerging economies.

The use of virtual and augumented reality technology, including mixed reality, 3D gaming, and holographic technology, is growing in popularity as technology becomes more accessible and affordable.

Several literature reviews have addressed adaptive VLEs, analyzing their advantages and disadvantages. Some reviews have focused on examining personalized information retrieval techniques (Steichen et al., 2012) and hypermedia methods (Knutov et al., 2009). Both studies reported promising results in the use of adaptive VLEs in different educational contexts as well as highlighted several limitations attributable firstly to the use of small samples of students in the evaluation of these environments and then to the main interaction with 2D environments neglecting other learning environments that use more advanced technologies to provide new learning experiences.

In light of the considerations illustrated so far, the research group on Artificial Intelligence in Education of the Department of Psychology and Education, Pegaso University (Italy), in collaboration with the Department of Agriculture, Food, Natural resources and Engineering, University of Foggia (Italy), has developed a work protocol that aims to integrate ITS within 3DVLE to evaluate a new AL system that increasingly responds to the needs of students and the technological progress that is investing the Digital Transformation in Education.

These new Adaptive 3D Intelligent Virtual Environments (A-3D-IVE) have been designed to accompany students throughout the entire learning process, collect feedback and structure adaptive responses capable of enhancing motivation to study, acting on intrinsic and extrinsic motivational variables, improving learning outcomes by responding to learning rhythms and styles, promoting educational success with a view to achieving a condition of well-being at school (Dato et al., 2021; Bevilacqua and Filippone, 2023).

The A-3D-IVE were built using the online platform Framevri.io, which is available online for free.

Framevr.io is an innovative online platform that offers powerful tools for the creation of 3D Virtual Worlds, making it a valuable resource in the field of education. Its uder.friendly interface and versatile features allow educators to design immersive, interactive environments that can transform traditional learning experiences.

Framevr.io supports the integration of ITS, enabling personalized learning paths that adapt to individual student needs, providing real-time feedback, and fostering autonomous learning.

In the educational context, Framevr.io is particularly effective for collaborative learning activities, as it allows students to engage with peers and instructors in real-time within a shared virtual space.

The platform supports the incorporation of multimedia resources, interactive simulations and gamified elements, making learning more engaging and relevant to digital-native learners.

Furthermore, educators can use Framevr.io to create virtual laboratories, historical reconstructions or dynamic models, enriching curriculum delivery across diverve disciplines.

By leveraging Framevr.io, institutions can address the growing need for technology-enhanced pedagogy, offering scalable solutions for remote, hybrid, or interperson learning.

Its compatibility with virtual reality devices further enhances the immersive experience, fostering deeper engagement and understanding.

As education evolves, platforms like Framevr.io are poised to play a pivotal role in shaping the future of teaching and learning.

The research is currently in full swing and the A-3D-IVEs thus structured have been used with students belonging to the three school segments of Primary School, Lower Secondary School and Upper Secondary School and in Higher Education, in the various disciplines, particularly in the STEAM disciplines and for learning the English language.

In particular, the pilot studies are being conducted in an Italian Comprehensive institute (I.C. Foscolo-Gabelli, Foggia, Apulia) across different educational levels: Kindergarten (one experimental group and one control group), Primary School (two experimental groups and two control groups) and Lower Secondary School (three experimental groups and three control groups).

The teaching practices within this institute are grounded in the DADA methodology (an Italian acronym for *Didactics for Learning Environments*).

In the Kindergarten and Primary School, the A-3D-IVE environments are employed as virtual and immersive learning settings for teaching English as a foreign language.

In Lower Secondary School, these environments support teaching in various subjects, including Technology (delivered using the CLIL methodology, *Content and Language Integrated Learning*), Scienze, Mathematics, Art and Geography.

In higher Education, A-3D-IVE environment are utilized as virtual and immersive learning platform for various disciplines. These include Scientifi English (offered in degree programs such as Digital Transformation Engineering, Nursing, Dentistry and Technical Diagnostic Health Sciences), English Language Laboratory (for the Primary Education degree program) and Food Microbiology (for the Food Science and Technology degree program).

For all these experiments, this new AL Adaptive Learning system is configured as a Virtual World characterized by personalized study material, personalized interactive exercises distributed by level of difficulty, personalized video lessons, and an Artificial Intelligence Tutor, who in the form of an avatar is programmed to meet the needs required by the specific discipline.

In particular, in higher education, this system is used to facilitate more effective student preparation for final exams, as well as to enhance meaningful learning and collaboration in studying.

Furthermore, there is no lack of immersive activities, so that the learning experience can be enjoyed both through the use of PCs, tablets and smartphones and in the Metaverse.

Thanks to A-3D-IVE, students can live immersive experiences in 3D, use educational content also in 3D, explore the 3D environment and interact with it (Dickey, 2005), communicate with other students and teachers and take advantage of the presence of an Artificial Intelligence Tutor.

These features make it possible to offer unique environments that provide numerous advantages to the learning process, maintaining high motivation of students who are highly involved, participating thanks to learning experiences that occur through simulations and intuitive spatial awareness of their position and actions (Chitarro and Ranon, 2007; Dalgarno and Lee, 2010; Duncan et al., 2012; Riley, 2008).

To evaluate the effectiveness of using A-3D-IVE, the work protocol includes monitoring the life skills identified by the World Health Organization

(WHO), the new digital competencies outlined in DigiComp 2.2, motivational variables, learning outcomes and the usability scale to assess the usability of the virtual worlds and the integrated ITS.

The results obtained in these first initial phases of the experimentation (data currently being collected) show how students find it completely fascinating to be able to study within such an innovative and captivating learning environment, which offers them the possibility of using the material necessary for their studies in a simple and direct way, having all the tools necessary to improve their knowledge immediately available, to experiment with what they have learned through interactive exercises and to measure their level of learning with intelligent tutors.

Although some students encountered initial difficulties in using A-3D-IVE due to their low digital skills, over time they were able to refine their abilities, acquiring ever greater mastery in the use of new digital technologies. A-3D-IVEs can therefore contribute to the strengthening of new *digital life skills* and the consolidation of *basic digital skills*.

Field research has shown how collaboration in studying was more effective. Studying in virtual worlds has allowed students to share the moment of learning by enhancing communication skills, problem solving and critical thinking in a process of silent learning that has improved attention levels and motivation for learning itself to the benefit of learning outcomes (Filippone et al., 2023).

The results obtained, until now, so far highlight a certain homogeneity in the different school levels both in terms of accessibility, usability and autonomy in use since, espite their younger age, the students of the lower secondary school have not encountered particular difficulties in using the tool as well as in the availability of devices at home. Certainly a criticality found is linked to the costs and economic availability that do not always allow the availability of personal computers or personal devices other than the smartphone. And although the A-3D-IVE are easily accessible also from smartphones their use is reduced and more complicated to manage. It therefore becomes necessary to investigate these criticalities in order to find suitable solutions to make this tool as usable as possible.

On the other hand, it was observed that university students were more immediate in using it because they had more suitable personal devices and because they showed greater mastery of basic digital skills.

The ongoing experimentation refers to the current school and academic year (2024/2025), but it will be repeated in subsequent years to enable, on the one hand, a longitudinal study and, on the other, a comparison between multiple samples analyzed across different academic and school years.

The use of A-3D-IVEs represents, as configured, a new field of exploration for the Eduverse. The Metaverse merges with the educational system, emerging as a large-scale interoperable network of 3D virtual worlds that are redirected in real time and can be experienced synchronously and persistently, transmitting a concept of extended reality transcending the limits of physical appearance and space (Filippone et al., 2023/b).

This innovative integration has the potential to revoluzionize traditional educational paradigms, fostering more immersive, inclusive and dynamic learning experiences (Rane et al., 2023).

4. Conclusions and Future Perspectives

3D Learning Virtual Worlds and ITS nowdays represent a paradigm shift in Education, introducing innovative ways to engage students and personalize learning paths.

Integrating AL into immersive environments could improve autonomy and academic and educational success.

The expansion of virtual environments and ITS in schools and universities can completely revolutionize education through the development of immersive multisensory experiences, overcoming the limits of the traditional classroom.

The application of such a structured technological tool can find applicability not only in STEAM disciplines but also in the perspective of a transversality of learning, enhancing not only the new digital life skills but also the life skills (Filippone and Bevilacqua, 2024).

The potential of the Eduverse thus becomes tangible also in the field of inclusion where it is necessary to expand studies aimed at evaluating the effectiveness of educational tools such as A-3D-IVE to improve learning motivation and accessibility, ensuring their adaptability for students with Special Educational Needs.

It is important to underline that these new technologies must be scalable and usable on a large scale and, despite the progress, there are still technical obstacles, mainly linked to the need for advanced infrastructures and the accessibility of these technologies to a wider audience (Hussain et al., 2024).

Teacher training is certainly a critical factor to address; the education and higher education system must focus on continuous and effective training in the field of new technologies.

The university and research in the field of Digital Transformation must support schools and teachers, so as to create an effective and productive training network.

Collaboration between Engineering, Psychology, Neuroscience and Pedagogy becomes essential in order to improve the effectiveness of ITS and VLE by integrating skills from different sectors.

Interdisciplinary collaborations are therefore strategic and in this perspective the development of Adaptive 3D Intelligent Learning Environments can concretely represent a driving forse for change for Virtual Reality and Eduverse in Education.

References

Abyaa A., Khalidi Idrissi M., and Bennani S. (2019). Learner modelling: systematic review of the literature from the last 5 years. *Educational Technology Research and Development, 67*: 1105-1143.

Adamu S., Awwalu J. (2019). *The Role of Artificial Intelligence (AI)* in Adaptive eLearning System (AES) Content Formation: Risks and Opportunities involved.*arXiv*, 1903.00934.

Agustianto K., Permanasari A.E., Kusumawardani S.S., and Hidayah I. (2016). Design adaptive learning system using metacognitive strategy path for learning in classroom and intelligent tutoring systems. In *AIP Conference Proceedings* (Vol. 1755, No. 1). AIP Publishing.

Akour I. A., Al-Maroof R. S., Alfaisal R., and Salloum S. A. (2022). A conceptual framework for determining metaverse adoption in higher institutions of gulf area: An empirical study using hybrid SEM-ANN approach. *Computers and education: artificial intelligence*, *3*, 100052.

Al-Bastami B.G., Naser S.S.A. (2017). Design and Development of an Intelligent Tutoring System for C# Language. *European Academic Research, 4:* 8795-8809.

Bell M.W. (2008). Toward a definition of "Virtual Worlds." *Journal of Virtual Worlds Research, 1*(1): 1-5.

Bevilacqua A., Filippone A. (2023). Divulgazione scientifica e didattica della Microbiologia. Un modello di didattica innovativa in una scuola secondaria di primo grado. *MeTis-Mondi educativi. Temi, indagini, suggestioni*, *13*(2): 68-84.

Biletska O., Biletskiy Y., Li H., and Vovk R. (2010). A semantic approach to expert system for e-assessment of credentials and competencies. *Expert Syst. Appl.*, *37*(10): 7003-7014.

Chittaro L., Ranon R. (2007). Web3D technologies in learning education and training: Motivations issues opportunities. *Comput. Educ.*, *49*(1): 3-18.

Dalgarno B., Lee M.J. (2010). What are the learning affordances of 3-D virtual environments?. *Brit. J. Educational Technol.*, *41*(1): 10-32.

Damaševičius R., Sidekerskienė T. (2024). Virtual worlds for learning in metaverse: a narrative review. *Sustainability*, *16*(5), 2032.

Dass S., Dabbagh N, and Clark K. (2010). Using virtual worlds: What the research says. *The Quarterly Review of Distance Education, 12*(2): 95-111.

Dato D., Cardone S., Di Pumpo M., Filippone A., Paoletti F., Romano C., and Ruggiero F. (2021). I DADA TEAMS: un'esperienza di didattica innovativa. *MeTis-Mondi educativi. Temi, indagini, suggestioni*, *11*(2): 292-306.

de Freitas S. (2008). *Serious virtual Worlds: A scoping study.* London, England: Coventry University, Serious Games Institute.

de Freitas S., Rebolledo-Mendez G., Liarokapis F., Magoulas G., and Poulovassilis A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology, 41(1)*: 69-85.

Delwiche A. (2006). Massively multiplayer online games (MMOs) in the new media classroom. *Educational Technology & Society, 9*(3): 160-172.

Dermeval D., Paiva R., Bittencourt I.I., Vassileva J., and Borges D. (2018). Authoring Tools for Designing Intelligent Tutoring Systems: A Systematic Review of the Literature. *International Journal of Artificial Intelligence in Education*, 28(3): 336-384.

Díaz J., Saldaña C., and Avila C. (2020). Virtual world as a resource for hybrid education. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(15): 94-109.

Dickey M.D. (2005). Brave new (interactive) worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments. *Interactive Learn. Environments*, *13*(1/2): 121-137.

DMello S., Olney A., Williams C., and Hays P. (2012). Gaze tutor: A gaze-reactive intelligent tutoring system. *Int. J. Human-Comput. Stud.*, *70*(5): 377-398.

Duncan I., Miller A., and Jiang S. (2012) A taxonomy of virtual worlds usage in education. *Brit. J. Educational Technol.*, *43*(6): 949-964.

Filippone A., Bevilacqua A. (2024). Lego-Kintsugi: a new teaching and educational methodology to enhance life skills and digital life skills, create well-being and educate happiness. *Italian journal of health education, sport and inclusive didactics*, *8*(3).

Filippone A., Montepeloso E.A., Leone R., and Bevilacqua A. (2023). Cooperative learning in virtual worlds: An innovative teaching and learning experience for STEAM education. *Italian Journal of Educational Research*, (31): 100-113.

Filippone A., Ferulli M., and Bevilacqua A. (2023/b). Virtual Worlds and Eduverse: a reflection on the body, space and learning in the metaverse. *Italian journal of health education, sport and inclusive didactics*, *7*(3).

Girvan C. (2018). What is a virtual world? Definition and classification. *Educational Technology Research and Development*, *66*(5): 1087-1100.

González-Brenes J.P., Mostow J. (2012). Dynamic Cognitive Tracing: Towards Unified Discovery of Student and Cognitive Models. *International Educational Data Mining Society*.

Hussain S., Meehan K., and Qadir J. (2024). Metaverse in education: opportunities and challenges. *Frontiers in Education*, 9, 1411841.

Jarmon L., Lim K.Y.T., and Carpenter B. S. (2009). Pedagogy, education and innovation in virtual worlds. *Journal of Virtual Worlds Research, 2*(1): 1-4.

Kelton A. J. (2008). Virtual Worlds? “Outlook Good”. *Educause Review*, *43*(5): 15-16.

Knutov E., De Bra P., and Pechenizkiy M. (2009). AH 12 years later: A comprehensive survey of adaptive hypermedia methods and techniques. *New Rev. Hypermedia Multimedia*, *15*(1): 5-38.

Kolchenko V. (2018). *Can Modern AI replace teachers? Not so fast! Artificial Intelligence and Adaptive Learning: Personalized Education in the AI age*. HAPS Educator.

Krahenbuhl K. (2016). Student-centered Education and Constructivism: Challenges, Concerns, and Clarity for Teachers. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 89*: 105 - 97.

Kulik J.A., Fletcher J.D. (2016). Effectiveness of intelligent tutoring systems: a meta-analytic review. *Review of educational research, 86*(1): 42-78.

Kye B., Han N., Kim E., Park Y., and Jo S. (2021). Educational applications of metaverse: possibilities and limitations. *Journal of educational evaluation for health professions*, *18*.

Lee H., Woo D., and Yu S. (2022). Virtual reality metaverse system supplementing remote education methods: Based on aircraft maintenance simulation. *Applied Sciences*, *12*(5), 2667.

McGee P., Carmean C., Rauch U., Noakes N., and Lomas C. (2007). Learning in a virtual world, part 2. In *EdMedia+ Innovate Learning* (pp. 3681-3685). Association for the Advancement of Computing in Education (AACE).

Merikko J., Kivimäki V. (2022). "Replacing teachers? Doubt it." Practitioners' views on adaptive learning technologies' impact on the teaching profession. *Frontiers in Education*, *7*, 1010255.

Mikić V., Ilić M., Kopanja L., and Vesin B. (2022). Personalisation methods in elearning-A literature review. *Computer Applications in Engineering Education, 30*(6): 1931-1958.

Mystakidis S. (2022). Metaverse. *Encyclopedia*, *2*(1): 486-497.

Nkambou R., Brisson J., Tato A., and Robert S. (2023). Learning logical reasoning using an intelligent tutoring system: a hybrid approach to student modeling. In *Proceedings of the AAAI Conference on Artificial Intelligence*, *37*(13: 15930-15937.

Occhioni M. (2017). Techland: Math and science in a virtual world. In *Handbook of research on collaborative teaching practice in virtual learning environments* (pp. 407-426). IGI Global.

Occhioni M., Beccaceci A., and Paris E. (2023). Environmental education in distance learning: using Virtual Worlds to link geosciences and sustainability. *Journal of Geoscience Education*, 1-15.

Panconesi G., Guida M. (2017). *Handbook of research on collaborative teaching practice in virtual learning environments*. IGI Global (Eds.).

Pannicke D., Zarnekow R. (2009). Virtual worlds. *Business & Information Systems Engineering*, *1*(2): 185-188.

Paris E., Boniello A., and Occhioni M. (2020). Geoscience Education using virtual worlds. *European Geologist European Geologist*, 39.

Park, S., Kim, S. (2022). Identifying world types to deliver gameful experiences for sustainable learning in the metaverse. *Sustainability*, *14*(3), 1361.

Park O.-C., Lee J. (2003) Adaptive instructional systems. *Educational Technol. Res. Develop.*, *25*: 651-684.

Peñarrubia-Lozano C., Segura-Berges M., Lizalde-Gil M., and Bustamante J. C. (2021). A Qualitative Analysis of Implementing E-Learning during the COVID-19 Lockdown. *Sustainability, 13*(6),

Quaicoe J.S., Ogunyemi A.A., and Bauters M.L. (2023). School-Based Digital Innovation Challenges and Way Forward Conversations about Digital Transformation in Education. *Education Sciences, 13*(4), 344.

Rane N., Choudhary S., and Rane J. (2023). Education 4.0 and 5.0: Integrating artificial intelligence (AI) for personalized and adaptive learning.. Available at SSRN 4638365.

Riley S.K.L. (2008). Teaching in virtual worlds: Opportunities and challenges. *J. Issues Informing Sci. Inf. Technol.*, *5*: 127-135.

Robben J. (2007*). Learning environments for the Net-generation learners*. Master thesis, Universiteit Twente.

Scott E., Soria A., and Campo M. (2016). Adaptive 3D virtual learning environments – A review of the literature. *IEEE Transactions on Learning technologies*, *10*(3): 262-276.

Shute V.J., Zapata-Rivera D. (2012). Adaptive educational systems, in *Adaptive Technologies for Training and Education*, Cambridge, U.K.: Cambridge Univ. Press, pp. 7-27.

Steichen B., Ashman H., and Wade V. (2012). A comparative survey of personalised information retrieval and adaptive hypermedia techniques. *Inf. Process. Manage.*, *48*(4): 698-724.

Taylor D.L., Yeung M., and Bashet A.Z. (2021) *Personalized and adaptive learning. Innovative learning environments in STEM higher education: Opportunities, Challenges, and Looking Forward*, 17-34.

Tian X. (2021). Scanning the Literature – From AR/VR to Metaverse. *IEEE Network*, 35(6): 8-9, November/December.

Xie H., Chu H.C., Hwang G.J., and Wang C.C. (2019). Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017. *Computers & Education*, 140, 103599.