

THE APPLIED NATURE OF THE APPLICATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN THE ORGANIZATION OF A PEDAGOGICAL EXPERIMENT

A NATUREZA APLICADA DA APLICAÇÃO DAS TECNOLOGIAS DE INFORMAÇÃO E COMUNICAÇÃO NA ORGANIZAÇÃO DE UMA EXPERIÊNCIA PEDAGÓGICA

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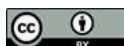
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Abstract

The study analyzes trends and features of ICT application within experimental pedagogy. Specific attention is paid to metaverse as one of the most innovative applied tools in the organization of pedagogical experiments. Metaverse, a virtual shared area that combines augmented reality and virtual reality technology, is frequently referred to as the "Internet of the future" due to its potential to transform online communication, collaboration, learning, and work. However, despite its potential strategic and economic uses, there is a scarcity of empirical data to support its instructional usefulness. This study examined the impact of Metaverse on

Resumo

Este estudo analisa as tendências e as características da aplicação das TIC na pedagogia experimental. Dá-se especial atenção ao metaverso, uma das ferramentas aplicadas mais inovadoras na organização de experiências pedagógicas. O metaverso, um espaço virtual partilhado que combina a realidade aumentada e a realidade virtual, é frequentemente referido como a "Internet do futuro" devido ao seu potencial para transformar a comunicação, a colaboração, a aprendizagem e o trabalho online. Contudo, apesar do seu potencial estratégico e económico, existe uma escassez de dados



teaching and learning by examining its advantages and challenges, describing the case of metaverse application in experimental teaching physics and geometry with the help of both standardized and specifically designed metaverses. This study's intended contribution is to provide real-life implications to educators and policymakers, particularly in the creation of education policies that align with current technology advancements, so contributing in accomplishing the overall objective of improving scientific education results.

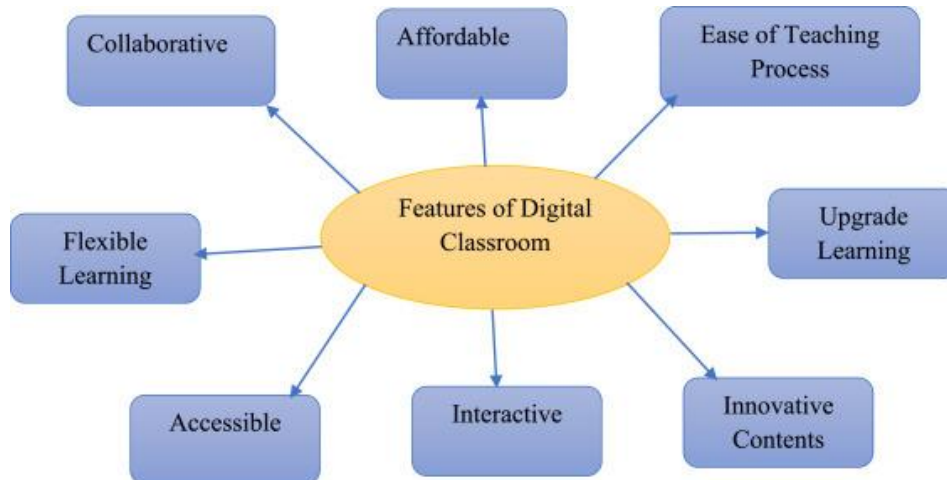
Keywords: Experimental Pedagogy. ICT. Metaverse. Digital Classroom.

empíricos que sustentem a sua utilidade didática. Este estudo examinou o impacto do metaverso no ensino e na aprendizagem, analisando as suas vantagens e desafios, descrevendo o caso da aplicação do metaverso no ensino experimental de física e geometria com a ajuda de metaversos padronizados e especificamente concebidos. A contribuição pretendida deste estudo é fornecer implicações práticas para educadores e decisores políticos, particularmente na criação de políticas educativas alinhadas com os avanços tecnológicos atuais, contribuindo assim para o objetivo geral de melhorar os resultados do ensino científico.

Palavras-chave: Pedagogia Experimental. TIC. Metaverso. Sala de Aula Digital.

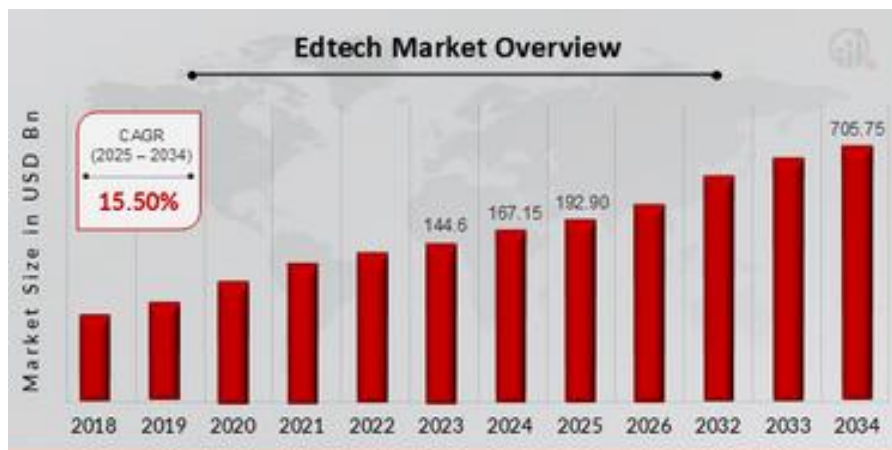
1 INTRODUCTION

Quality education is a key component of the United Nations' 2030 Agenda for Sustainable Development. It seeks to guarantee inclusive and equitable quality education for all. Digital technology emerged as a critical instrument for accomplishing this aim. The fast growth of digital technology is altering the educational environment, necessitating an urgent call for a renewed emphasis on technology-enhanced education. Traditional classroom training falls short of creating an instant learning environment, speedier assessments, and more participation. In contrast, digital learning tools and technology fill the gap. Traditional learning approaches just cannot match some of the efficiencies that such technologies give. Figure 1 clearly shows the benefits of a digital classroom.

Figure 1*Digital classroom features*

Source: Haleem, Javaid, Qadri, & Suman, 2022

Businesses in the educational technology industry are constantly looking for new ways to improve education quality and increase access. The Edtech Market is expected to expand from USD 192.90 billion in 2025 to USD 705.75 billion by 2034, with a compound annual growth rate (CAGR) of 15.50% over the forecast period (2025-2034) (see Fig. 2). Additionally, the Edtech Market was estimated at USD 167.15 billion in 2024.

Figure 2*Edtech Market, 2025 – 2034 time period (USD Billion)*

Source: Mundel, 2025

Despite the widespread use of technological tools and solutions in classrooms,

there is still a significant deficit in pedagogical theories that enable technology-enhanced learning settings. This rising trend emphasizes the need for pedagogical solutions, novel teaching methodologies, and new concepts for learning design as a field to study and create what is now known as “smart pedagogy” (Daniela, 2019). Furthermore, pedagogy must broaden its theoretical foundation to integrate and adapt teaching and learning concepts to the new context of the technology-enhanced learning environment. This includes learning about educators’ changing responsibilities, effective teaching techniques, and knowledge acquisition research and assessment, especially as learners become more involved in creating their educational experiences. In this spirit, actual experiments and examples of the use of applied ICT in the educational process are becoming increasingly important. The results of such experiments can help to fill the practical base and shape the theoretical landscape of the most recent ICT applications in educational processes, as well as contribute to teachers’ continuous professional development and acquisition of new skills in the field of using ICT to improve the teaching and learning landscape. With this in mind, we developed and implemented an experiment which demonstrates opportunities and effectiveness of metaverse solutions application in college educational process. In addition to didactic performance of the proposed solution, the experiment represents a practical demonstration of the applied nature of the application of information and communication technologies in the organization of a pedagogical experiment.

2 MATERIALS AND METHODS

The theoretical and methodological foundations of the study are the main provisions of the theory and practice of informatization of education, theoretical approaches to the development of new generation standards on a modular-competence basis, the theory and methodology of pedagogical research, the theory of designing information systems, the basics of modeling complex systems, the methodology of creating and developing information systems and technologies. A mixed approach of research is applied, involving content analysis of literature and conducting of pedagogical experiment, the results of which served as a triangulation for insights gained within content analysis procedure. Taking into account the novelty of the area of research,

constructivism paradigm of science was chosen as an overall philosophical framework.

3 RESULTS AND DISCUSSION

Technological developments provide a fresh possibility for experimental pedagogical growth in every educational facility. Experimental Pedagogy empowers education innovators via critical experience learning. At the core of experimental pedagogics is the concept that education is, by definition, a transdisciplinary endeavor: it stems from the numerous disciplines that comprise its contents, as well as the interdisciplinary perspectives that feed into its process. Education, at its core, lends meaning to our world experiences by pushing us to make sense of the chaotic inputs of our unscripted reality. The relationship between education and existence is examined through five different “levels” of analysis: the cognitive level, the individual level, the group level, the societal level, and the global level. Experimental pedagogics offers a comprehensive framework for what would otherwise be an overwhelming whole (Schulze, 2023). The epitome of experience learning is experimental pedagogy. The curriculum consists of three “tracks”: the project track, the education track, and the reflection track. The purpose of each of these courses is to provide students the opportunity to encounter progressively avant-garde teaching methods. Therefore, it becomes crucial to consider the practical character of information and communication technology use while planning a pedagogical experiment.

The metaverse is one of the most creative uses of ICT for educational research, allowing for a variety of models and experimental domains. In response, experts believe that STEAM education is the ideal environment for using the metaverse (Canfarotta, & Pipitone, 2024). In order to emphasize the value of the relationship between scientific and humanistic disciplines, STEAM courses which incorporate art into STEM subjects are also becoming more popular. This emphasizes the significance of creativity in problem-solving (Conradty, & Bogner, 2018). Through the clever and moral application of technologies (tools), Human-Centered Design (HCD) allows the humanistic (meanings) and scientific (methods) components to come together and become tangible and real. The Italian National Education Association (National Education Association., 2015) states that these courses are designed to help students acquire the four Cs, which are abilities

that are essential for 21st-century citizens: (i) Critical thinking: the capacity to solve an issue by analyzing every detail in an objective and analytical manner; (ii) Communication: the capacity to converse with others; and (iii) Collaboration: the capacity to grow in the STEM approach through the project-based learning methodology. (iv) Creativity: using transversal thinking and coming up with novel ideas (Jang, 2016).

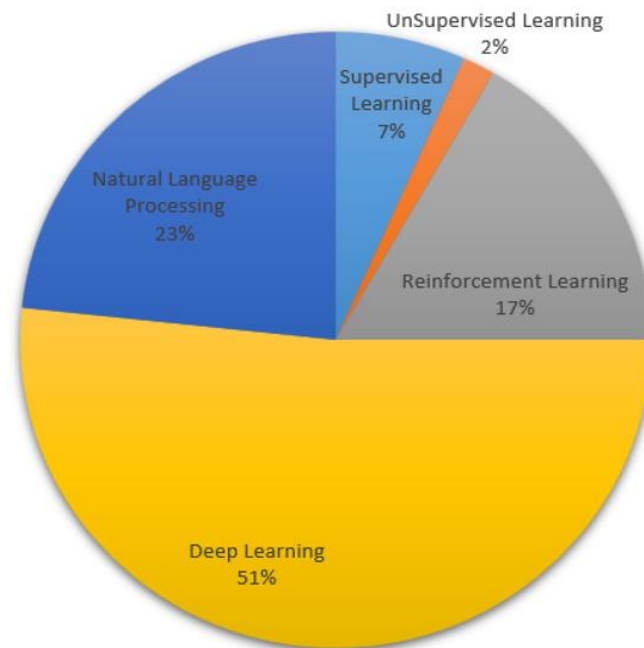
Recently, STEAM education principles are widely adopted in Ukrainian education. Ukrainian researcher Lebid (2024) emphasizes that STEAM technologies will help to educate graduates who will be able to solve non-standard situations, defend their point of view, constructively criticize, support each other in a team, generate ideas, know soft skills, along with well-developed hard skills, which this technology takes into account, find creative potential in their activities. She notes the following principles of STEAM approach: teamwork, where students unite in groups and solve a practical task through project activities; the result of the work carried out in the classroom can be used in practice when solving a problem that may arise in the community, educational institution, enterprise; interdisciplinary connections during training, the task requires knowledge from several disciplines to solve it; coverage of key disciplines, as for an engineer: physics, chemistry, mathematics, modern technologies, engineering disciplines, while involving subjects such as literature, fine arts, music, architecture. The Road-STEAMer initiative, which included Ecsite, the Junior Academy of Science of Ukraine (JASU), and the Institute of the Gifted Child of the National Academy of Pedagogical Sciences of Ukraine, greatly advanced the discourse on STEAM education in Ukraine by 2024. However, initiatives to integrate STEAM ideas into school and college curriculum in Ukraine remain dispersed and lack a comprehensive structure. In our perspective, the introduction of metaverse possibilities can enhance the situation, particularly when used as a landscape in instructional trials in diverse directions.

One of the most significant applications of the metaverse, with great potential for the future, is education, according to specialists. According to Suzuki et al. (2020), Prieto et al. (2022), and Rospigliosi (2022), the metaverse can be used as a new educational setting. As a result, the metaverse in education can be seen as an educational setting that is enhanced by technologies related to the metaverse that combine aspects of both virtual and real educational environments. It enables students to interact with a variety of materials in real time (such as avatars, intelligent NPCs, or virtual learning resources) and

access the educational environment through wearable technology regardless of time or location. People may feel present as though they are in an actual educational setting as a consequence. From this angle, it is evident that integrating the metaverse into the classroom may provide students with a wealth of incredible learning possibilities.

The usage of the metaverse in educational contexts has increased dramatically in recent years, particularly as major tech companies have shifted their focus to virtual worlds and immersive technology. Many current emergent technologies, including as blockchain, virtual reality (VR), augmented reality (AR), mixed reality (MR), digital twins, artificial intelligence (AI), and the Internet of Things (IoT), are projected to be included and integrated into the metaverse. The metaverse's capacity to generate high degrees of immersion and nurture a sense of presence in order to make virtual interactions appear authentic and meaningful will be critical to its success. In addition to MR and AR, VR technologies will be employed to generate immersion. These technologies, categorized as extended reality (XR), have grown rapidly in recent years. Augmented and virtual reality technologies are used to build immersive learning environments. In general, the metaverse is a huge digital ecosystem or virtual area that facilitates the transition from the actual world to virtual surroundings. It can be employed in educational situations such as space exploration, chemical experimentation, and flight simulation training, when carrying out physical experiments is difficult or risky. Furthermore, the introduction of artificial intelligence and the metaverse into educational settings has significantly improved the learning environment, resulting in the development of AI-driven teaching systems that are tailored to each student's specific learning preferences and pace.

According to the findings of a thorough assessment of the literature, Almeman et al. (2025) believe that incorporating the metaverse into the classroom and applying AI applications will increase learning by supporting students in comprehending and mastering a variety of academic fields. The study found that recent technological breakthroughs, notably the usage of AI in the metaverse, have had a significant impact on schooling. AI approaches, including metaverse techniques, have a lot of promise to improve teaching methods, according to an examination of $N = 60$ technical contributions from all qualified publications. These included deep learning, reinforcement learning, supervised and unsupervised learning, and natural language processing. The authors offer a schematic (see Fig. 3) that shows the AI teaching techniques used in the metaverse.

Figure 3*AI techniques applied in the metaverse for education*

Source: Almeman, et al., 2025

A detailed examination of Figure 3 reveals some crucial details about the use of AI techniques in metaverse learning settings. First, the most popular AI technique is deep learning (51%), which emphasizes its vital role in handling complex educational data and enabling innovative features like personalized learning and immersive simulations. Deep learning's use also demonstrates how important it is for improving augmented reality experiences and gauging students' reaction to visual stimuli. Notable allusions to natural language processing (23%) are particularly intriguing; this is most likely due to the fact that learning environments necessitate communication and engagement, which has made it easier to create applications like chatbots, virtual assistants, and automated feedback systems. By tailoring information to users' behaviors in the metaverse, reinforcement learning (17%) aims to customize learning paths. The lower focus given to supervised learning (7%) and unsupervised learning (2%) suggests that, although they are important for data clustering and predictive analytics, they are not as important for the immersive and participatory aspects of the metaverse.

Researchers have focused a lot of emphasis on the use of the metaverse in education, particularly in light of the limitations of conventional 2D teaching techniques,

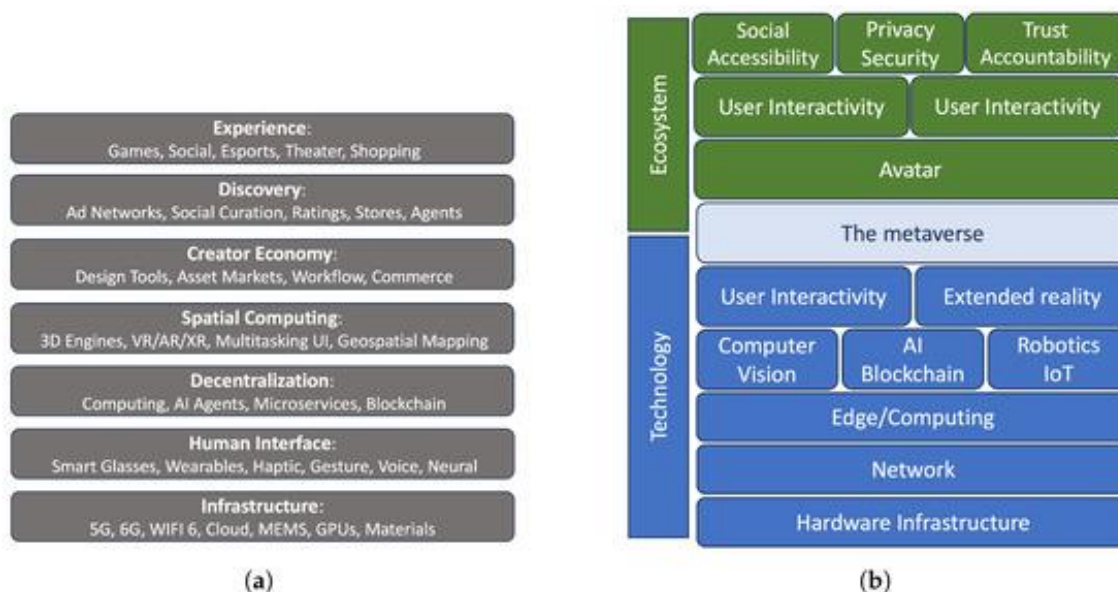
which were brought to light during the COVID-19 pandemic (Singh, 2024). From the standpoint of educators, the metaverse's primary benefit is its ability to improve learning through immersive, interactive, and cooperative experiences. Immersion activities will improve students' comprehension by enabling them to investigate difficult ideas practically (Kabilan, 2023). Additionally, interactive components like 3D models and simulations will improve learning's effectiveness, fun factor, and participation rate. The investigation of real-world situations in several fields will be made possible by these interactive components. Furthermore, instruction will become more realistic and interesting as a result of instructors being able to hone their abilities with augmented reality (AR) technologies in metaverse environments (Jagatheesaperumal, Ahmad, Al-Fuqaha, & Qadir, 2024). There are several educational advantages to the metaverse. Through avatars in a virtual environment, students from all over the world may communicate and learn from one another, giving them extensive access to information. Through experiential learning, students may investigate and practice difficult, real-life activities that would not be possible in the real world. The metaverse promotes communication and cooperation with people outside of their normal circle and tailors instruction to meet the needs of each unique student (Lin, Wan, Gan, Chen, & Chao, 2022, December). Furthermore, the development of virtual universities which offer extremely dynamic and cooperative learning environments can result from the metaverse. By providing more dynamic and captivating platforms than conventional online learning tools, this can improve the educational experience. The adaptability and usefulness of the metaverse in education are further highlighted by the possibility of developing virtual spaces where students may participate in events like orientations, campus visits, and even internships (Dwinggo Samala, 2023). This can help foster virtual sociability and the development of virtual learning groups.

Developing a metaverse that accurately reflects the intricacies of the real world is a difficult undertaking that calls for much theoretical investigation at the framework level. A well-defined framework must be established before deployment to direct the development process and offer a strong basis for the architecture of the system. By outlining the essential elements, interactions, and data flows required for the successful integration of artificial intelligence, virtual environments, and user interfaces, this framework plays a significant role. Jon Radoff's technique is one of the most popular and

much debated (Kye, Han, Kim, Park, & Jo, 2021; Tsai, 2022). Figure 4a depicts the suggested framework’s seven tiers: infrastructure, human interface, decentralization, spatial computing, creator economy, discovery, and experiences, which stress the metaverse’s technological and experiential components. Lee et al. (2024) developed a model (see Figure 4b) that divides the metaverse into two basic categories: ecology and technology, in order to support a single virtual world. It describes the interconnections between these two regions. Eight important enabling technologies, including XR, AI, blockchain, and edge computing, may be identified based on technology. These technologies enhance the metaverse’s experience features and facilitate user interactions. The ecosystem component prioritizes user-centric components that must adhere to current real-world regulations, such as content creation, the virtual market, and social norms.

Figure 4

Metaverse frameworks. (a) The layers of the metaverse framework by Jon Radoff. (b) The layers of the metaverse framework



Source: Lee et al. (2024)

It is crucially important to differentiate the metaverse from independent virtual reality systems and applications. The metaverse is a more full integration of technologies, such as digital twins, AR, MR, VR, IoT, and so on, with virtual reality playing an important role. The smooth blending of virtual and physical experiences is made possible

by these technologies. Furthermore, the metaverse is meant to be a networked ecosystem of virtual spaces that facilitates interoperability and continuity of user experiences across several platforms, as opposed to a collection of separate virtual worlds.

In order to illustrate the potential of using the metaverse in educational trials, we investigated how college students' academic performance and motivation in science and math were affected by metaverse technology. 43 students in the control group continued to receive education using traditional methods, whereas 44 students in the experimental group spent a semester in the Metaverse utilizing a quasi-experimental methodology (suggested and tested by Lee et al. (2024)) at the Nemishayeve Vocational College (Nemishayeve, Kyiv region, Ukraine). The students were selected and divided into two groups using a lottery method. We selected the free and age-appropriate Recroom metaverse for the students.

A validated science achievement exam and a motivation scale were among the tools used to collect the data. As opposed to the control group, which received an average post-test score of 66.8 ($t = 2.3$, $p < 0.05$), the experimental group's nodes showed statistically significant improvement, with an average score of 73.4. Additionally, the experimental group's motivation ratings were marginally greater than those of the control group, with a mean of 27.9 vs 17.1 ($t = 5.75$, $p < 0.05$). The impact sizes for motivation and academic success were rather high: random effect = 1.086; fixed effect = 1.091. These findings show how Metaverse technology has the potential to completely transform scientific education for children. In order to improve performance and favorably impact students' attitudes toward improved learning environments in educational institutions, this technology may prove to be a useful teaching tool in scientific classrooms.

The purpose of the Academic Achievement Test in Science was to assess the academic performance of the experimental and control groups of students both before and after the test. The "Matter and Energy" unit from the science book served as the basis for the test's content. With a total score of 40 points, the test had 20 multiple-choice questions and 20 true/false questions about scientific terminology. Expert judgment was used to determine the test's validity, and Cronbach's alpha (0.84) indicated that it was sufficiently reliable. Acceptable levels were indicated by the test items' difficulty index, which varied from 31 to 59, and discrimination index, which ranged from 0.33 to 0.70.

To assess college students' motivation for studying science both before and after

utilizing Metaverse technology, the Motivation Scale for studying was created. The four aspects of (1) desire to study science and a positive attitude toward it, (2) attention on learning and completing tasks, (3) stimulation in the learning environment, and (4) ambition and perseverance were chosen because they were relevant to the Metaverse environment and scientific topic. The scale's original version included 25 items, and a five-point Likert scale was used to score replies.

The methods used in this study were multi-step. The Academic Achievement Test in Science and the Motivation Scale for Learning were the first research tools created for this subject. Samples were then selected and split into the experimental and control groups. The motivation scale and accomplishment exam were administered as pre-tests to both groups. While the control group employed traditional teaching techniques, the experimental group used the Metaverse to follow instructions in the "Soils structure" lesson (specialty "Agrarian science"). Lastly, post-tests were offered to both groups following finishing of the work with metaverse. The study topics were addressed using descriptive statistics, such as mean and standard deviation, and inferential statistics, such as independent sample t-tests, analysis of variance (ANOVA), effect size, correlation coefficients, and Cronbach's alpha.

The weighted value ratings and matching motivation levels for the replies on a five-point Likert scale: "Strongly Agree" gets a score of 5 (4.31–5.00), which indicates a very high level of motivation; "Agree" gets a score of 4 (3.51–4.30), which indicates a high level of motivation; "Neutral" gets a score of 3 (2.71–3.50), which indicates a medium level of motivation; "Disagree" gets a score of 2 (1.81–2.70), which indicates a low level of motivation; and "Strongly Disagree" gets a score of 1 (1.00–1.80), which indicates a very low level of motivation. Based on scores, this table offers a clear foundation for assessing motivation and agreement levels.

After reviewing the questions, five faculty members with expertise in scientific teaching methods provided an assessment of the items' accuracy for each type of dimension and their importance for determining agreement. About 80% of the reviewers agreed, which validated the tool's validity and the level of consensus. The final scale included 24 components and four dimensions after changes were made in response to the panel of reviewers' comments. The validity of the scale was then evaluated, The scale had an overall Cronbach's alpha reliability coefficient of 0.902. The dependability

coefficients for the scale dimensions were between 0.922 and 0.932. These coefficients are both adequate and acceptable, showing that the scale is sufficiently reliable.

The researcher created courses that are compatible with virtual presentations, employing the platform's various capabilities to help convey content.

Table 1 shows no significant difference in results between the experimental and control groups on the academic achievement exam in science (particularly, the achievement test for the Matter and Energy unit, administered pre- and post-application).

Table 1

Pre-test academic achievement in science

<i>Group</i>	<i>Mean Score</i>	<i>Standard Deviation</i>	<i>Calculated "T" Value</i>	<i>Tabular "T" Value</i>	<i>Statistical Significance</i>
CG	64.8	11	3.7	2.2	Not statistically significant
EG	66.3	11.5			

To compare the experimental and control groups' scores, we employed an independent sample t-test. To identify statistically significant differences between the experimental and control groups' performance on the scientific achievement exam, we employed means, standard deviations, and t-values. The findings are displayed in Table 2.

Table 2

T-value and degree of significance for the control and experimental groups in academic attainment

<i>Group</i>	<i>Mean Score</i>	<i>Standard Deviation</i>	<i>Calculated "T" Value</i>	<i>Tabular "T" Value</i>	<i>Statistical Significance</i>
CG	66.8	12.10	2.3	1.97	Statistically significant
EG	73.4	10			

At a significance threshold of 0.05, the estimated t-value increased significantly when compared to the tabulated value (1.97). This shows that there were statistically significant variations in the scientific academic achievement exam results between the experimental group, which was taught using the Metaverse methodology, and the control group, who was taught using traditional techniques.

The second part of the experiment involved creating a custom built Metaverse

based on the NVIDIA Omniverse platform and utilizing it to teach geometry. To facilitate collaboration, simulation, and real-time 3D graphics creation, the NVIDIA Omniverse platform includes a set of workflow-focused core programs such as Omniverse Create/USD Composer for scene composition and Isaac Sim for robotics, among others. The designed Metaverse was called UniverseN.

The model (digital twin) of the classroom was developed. The classroom in UniverseN was created using the design program SolidWorks. Augmented motion technology was used to build interactive avatars. Each student may have their own individualized avatar for immersive and engaging learning experiences. In a virtual classroom, students can participate in a combination of avatars and video-based activities. Students were doing immersive and interactive learning in vector geometry within UniverseN. This is a revolutionary technique that aims to help students understand abstract mathematical topics through interactive manipulation. Abstract ideas such as Vector Cross Product, Skewline Distance, Left-hand Rule, and so on become much more concrete when students interact with virtual objects while studying. This immersive and engaging method will benefit students by increasing self-efficacy, situational interest, and other learning outcomes. The Metaverse facilitated students' collaboration and collaborative effort on projects.

A small-scale survey of eight participants was undertaken using the Technology-Rich Outcome-Focused Learning Environment Inventory (TROFLEI) (Tan, Ngo, Chandrasekaran, & Cai, 2013). Table 3 includes the eight survey questions used to elicit each participant's thoughts about UniverseN. Options for responses were as follows: 1 Strongly Disagree; 2 Disagree; 3 Neutral; 4 - Agree; 5 Strongly Agree.

Table 3

Survey TROFLEI questions, offered to each participant

<i>No.</i>	<i>Questions</i>	<i>Detailed Descriptions</i>
Q1	Student Cohesiveness	The level to which you can support and assist other students in the UniverseN environment (for example, I can successfully collaborate with others in UniverseN)
Q2	Student Involvement	The amount to which you are attentive, participate in discussions, are ready to do extra effort, and enjoy your UniverseN experience (for example, I can discuss ideas and express my thoughts while using the UniverseN platform)
Q3	Student Investigation	The amount to which you can use inquiry skills and methods to issue solving and research in UniverseN (for example, I can do useful

		functional analysis within UniverseN)
Q4	Student Cooperation	In the UniverseN environment, the degree to which you can work together instead of competing on learning assignments (e.g., I can interact with other students successfully and establish teamwork in UniverseN)
Q5	Differentiation	The degree to which educators can accommodate learners and offer customized experiences at various levels (e.g., I can work at my own speed within my own aptitude, rate of learning, and interests in UniverseN)
Q6	Equality	The degree to which teachers in the UniverseN environment treat you fairly (for example, I have the same capabilities and say as other students in the UniverseN environment)
Q7	Creativity	The degree to which the VR activities in UniverseN allow using creativity in thinking and developing (e.g., I can freely utilize my creativity in UniverseN)
Q8	UniverseN	The amount to which you find VR beneficial for assessing real-world applications or use cases (for example, I believe UniverseN is good for analyzing real-world challenges).

As the result of survey, there were no students who chose 1 Strongly Disagree, 2 Disagree, and 3 Neutral options of answers. Most of responses were in the category 5 Strongly Agree and some – in the category 4 Agree. Scores (out of 5) for all 8 questions were distributed as follows: Q1 – 4.625, Q2 4.625, Q3 4.5, Q4 4.5, Q5 4.625, Q6 4.75, Q7 4.625, Q8 4.625.

This demonstrates the effectiveness of Metaverse methodologies in teaching science content and improving students' academic accomplishment, as well as developing teamwork skills and creative thinking. Students participate in a learning environment that resembles reality, which improves knowledge acquisition and retention, resulting in improved academic accomplishment. These findings are congruent with those reported in the previously studied literature.

It was discovered that using Metaverse technology improved both academic performance and learning motivation in college science classes. The Metaverse is incredibly fascinating due to its three-dimensional setting, and because the students were already used to playing online games, they were able to better comprehend the scientific principles taught. Students in the Metaverse setting are allowed to solve issues with the knowledge they get; hence, self-motivation is valued as part of the teaching and learning process, and metaconnections are encouraged within scientific subject. Motivation, however, represents the amount of involvement that Metaverse technology fosters among students. Simulations, such as the Metaverse's energy transformation simulation, improve

comprehension and are connected to the capacity to interest students. One of the primary benefits of Metaverse apps is that students are compelled to learn collaboratively and exchange knowledge and, maybe, ideas with one another and professors, which boosts motivation.

Overall, this study not only offers some important evidence regarding the effects of Metaverse technology on college science learning, but demonstrates the possibilities of metaverse application in pedagogical experiments.

4 CONCLUSION

According to the research, the metaverse has the potential to play an important role in education. The emergence of developing technologies can open up new options for using the metaverse in education. As a result, for future study, a number of prospective metaverse-related research concerns in education and experiential pedagogy might be proposed:

1. Designing metaverse models or frameworks for educational use. So far, the metaverse is under building, and it requires high-quality infrastructure that is tailored to common habits. The metaverse's designs and frameworks, which include hardware and software, serve as the foundation for educational processes.
2. Implementing metaverse laws and concepts in education. Although the metaverse has many benefits for education, the fifth part discusses potential privacy, security, and moral issues. Learners, particularly teens, are at a key stage of physical and mental growth. Current challenges in educational activities might have a significant influence on their future lives. As a result, strong norms in metaverse-based educational contexts must be established and enforced immediately.
3. Investigating the attitudes of college administrators, teachers, and parents regarding using the metaverse for educational reasons. It is possible that teachers and college administrators will face both opportunities and obstacles when they use the metaverse. Furthermore, the metaverse has the potential to transform how students study both at college and at home. As a result, it is worthwhile to investigate the views of college administrators, teachers, and parents regarding using the metaverse for educational purposes, as this information is predicted to

be useful for future metaverse design, administration, and educational practice.

4. Teacher professional development in respect to the metaverse. Teachers are often regarded as playing a critical role in achieving educational achievement and implementing educational change. As a new educational tool, the metaverse has the potential to provide instructors with a variety of options. In order to do this, it is challenging and multifaceted to figure out how to give teachers a good foundation for teaching by embracing the metaverse (Lee, & Jeong, 2022). Additionally, the metaverse opens up new possibilities for teacher education in a whole different virtual setting. Therefore, professional growth and teacher education might be important parts of metaverse education research.
5. Exploring the metaverse's cognitive and non-cognitive influence on learners' learning. This might be a potential avenue for educational scholars to pursue. Exploratory research is necessary to compare the academic performance of students of different grades and ages utilizing the metaverse and traditional technologies since the educational implementation and paradigm in relation to the metaverse may differ dramatically from current schooling. Simultaneously, it is important to look into how the metaverse influences learners' cognitive (like attention and memory) and non-cognitive (such learning attitude and motivation) aspects in such a novel setting with high levels of immersion, presence, and freedom. Additionally, through observation and analysis, educators can obtain a comprehensive understanding of how students behave in the smart environment that combines the virtual and real worlds. This will enable them to comprehend the social impact of the metaverse and help create more effective learning strategies for students.
6. Comparing the efficacy of metaverse learning and teaching to traditional learning settings, as well as cross-platform. When introducing new technology into education, comparative analysis is essential to identify the most successful educational settings for teaching and learning. For example, the questions below look rational: Will learners do better in the metaverse than they would in a traditional classroom or via screen-based remote learning? Will learners experience the same views and performance across metaverse platforms?
7. Proposing fresh ideas for the methodological and educational paradigm in line with

the metaverse. Because of its unique characteristics, the metaverse may be viewed as a perfect environment for future education, in which the traditional pedagogical paradigm shifts from static to dynamic representation and learners progressively become the focal point of the teaching-learning process. In this way, the traditional educational paradigm will be challenged. With this in mind, it is vital to look into new methodological and instructional techniques that may be integrated into the metaverse setting.

8. Exploring current pedagogical theories for metaverse-based education. As a novel notion, the metaverse in education will spark new pedagogical debates. It is vital to analyze and improve current technologically enhanced teaching approaches. Furthermore, based on the metaverse's innovative qualities, academics are expected to propose new educational theories for its application, such as embodied cognition, situated cognition, distributed cognition, extended cognition, flow theory, cognitive load theory, and the technology acceptance model.
9. Creating an educational evaluation system based on the metaverse or using it as an assessment tool.

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Authors’ Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study’s findings are fully available within the article.

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