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THE USE OF IMMERSIVE TECHNOLOGIES IN EDUCATION: ANALYSIS OF SCIENTIFIC STUDIES IN THE SCOPUS BIBLIOGRAPHIC DATABASE FOR THE PERIOD 2015–2023

Contemporary societal challenges, such as COVID-19 and military conflicts, restrict or significantly limit students' access to educational facilities, laboratories, specialized classes, and other educational infrastructure. These changes pose new challenges to the education system. Access to laboratories and specialized training facilities is crucial for the training of various professionals, including engineers, navigators, pilots, doctors, and science teachers. The outcomes of their training directly depend on access to the tools and equipment they will use in their future professional activities. Additionally, an important aspect of effective education is considering the characteristics of the current generation of learners and their educational needs. One promising direction for structuring educational processes is the use of immersive technologies, which form the basis for creating a metaverse. Given the rapid evolution of the metaverse concept, substantial investments in metaverse technology development, active growth across various business sectors within the metaverse, and the significant impact of these technologies on various facets of societal life, it is crucial to comprehend the current scale of the metaverse and its subsequent implications, particularly for the education system. We conducted an analysis of research conducted at the intersection of the concepts "immersive", "metaverse", and "education" (in various spellings and extended to specific immersive technologies such as AR, VR, MR), available in the Scopus database, with a focus on the period from 2018 to 2023. The article presents the methodology for selecting and processing data. The data selection process was particularly processed using a scientific torture method, allowing the identification of fields with the most significant number of studies on the

chosen theme, clustering the directions in which the research was conducted, identifying authors actively involved in the researched theme, and determining prospective directions for further research.

Keywords: *immersive technologies; metaverse; education*

ВИКОРИСТАННЯ ІММЕРСИВНИХ ТЕХНОЛОГІЙ В ОСВІТІ: КОНТЕНТ-АНАЛІЗ ДОСЛІДЖЕНЬ У НАУКОМЕТРИЧНІЙ БАЗІ SCOPUS ЗА 2015-2023

Сучасні виклики суспільства, як-от: COVID-19, військові конфлікти, що унеможливлюють або суттєво обмежують доступ студентів та учнів до лабораторій, тренувальних комплексів, спеціалізованих класів та іншої освітньої інфраструктури, ставлять нові завдання перед системою освіти. Доступ до лабораторій і тренувальних комплексів є важливим у розрізі підготовки широкого кола майбутніх фахівців: інженерів, штурманів, пілотів, лікарів, учителів природничих наук та ін. Результати їхньої підготовки залежать від доступу до знаряддя та обладнання, яке вони використовуватимуть у подальшій професійній діяльності. Також важливим аспектом організації ефективного навчання є врахування особливостей сучасного покоління здобувачів освіти та їхніх освітніх потреб. Одним із перспективних напрямів побудови освітнього процесу є використання іммерсивних технологій, що є підґрунтям створення метавсесвіту (metaverse). З урахуванням швидкої еволюції концепції метавсесвіту, значних інвестицій у розроблення технологій метавсесвіту, активного розвитку різних сфер бізнесу у метавсесвіті та суттєвого впливу даних технологій на різні сфери життя суспільства, важливим є розуміння поточного масштабу метавсесвіту та подальших наслідків, зокрема для системи освіти. Проаналізовано результати досліджень, що виконувались на перетині понять «іммерсивний», «метавсесвіт» та «освіта» (у різних написаннях і з розширенням до конкретних іммерсивних технологій, як-от: AR, VR, MR), представлені у базі наукових публікацій Scopus з акцентом на період 2018–2023 років. У статті представлена методологія відбору та опрацювання даних. Проведений відбір даних було опрацьовано зокрема методом наукового катування, що дало можливість виділити галузі, в яких є найбільша кількість досліджень з обраної тематики; кластеризувати напрями, у яких проводились дослідження; авторів, які активно займаються досліджуваною тематикою, а також визначити перспективні напрями подальших досліджень. Зазначимо, що кожен із виділених напрямів використання метавсесвіту та іммерсивних технологій в освіті має широке коло питань, що потребують глибшого наукового пошуку.

Ключові слова: *іммерсивні технології; метавсесвіт; освіта*

1. INTRODUCTION

Statement of the problem. The increased interest of professional communities in virtual reality tools and artificial intelligence technologies poses a challenge for researchers to explore their potential applications and prospects in various fields. Educational technologies have long utilized various immersive technologies, particularly virtual worlds, for practicing practical skills among future professionals. The results of research on such education are reflected in numerous publications. However, these studies are conducted independently across different sectors. Timeframes also matter, as technological development is not linear; the attention of researchers gradually shifts or returns to one technology or another. New terms emerge, either as successors, combinations of technologies, or innovations. In the pursuit of distinguishing their product among others, companies seek new names. This also influences the terminology used. Therefore, tracking general trends in the further development of such technologies, as well as potential topics for further research, will help direct future research in this field.

Scientists are continually seeking ways to enhance the education system, enabling future professionals to best meet labor market demands and possess well-developed soft skills and hard skills. Universities must consider the pace of modern technological advancements and their impact on various aspects of societal life, particularly on the education system. Among the actively evolving directions being implemented into the education system are adaptive learning, STEM education, educational systems based on augmented (AR), virtual (VR), or mixed (MR) reality technologies, and extended reality (XR). The implementation of immersive technologies (AR, VR, MR, XR) is a current and research-demanding topic.

Immersive technologies refer to a set of technologies based on interaction with the virtual world, the so-called metaverse. The use of immersive technologies is closely linked to other IT technologies that have recently also experienced significant growth due to technological advancements. Metaverses could become a new step in the development of education, harmoniously combining the achievements of pedagogical and psychological sciences on the basis of new technological solutions. It's important to instill in educators, especially future teachers, an awareness of the rapid changes in the world, the emergence of new digital tools, and the potential for using them to develop students' competencies, support their growth, and cultivate a reflective approach.

Analysis of recent research and publications. The use of technologies, particularly immersive ones, in education is being extensively explored by numerous researchers. The results and various aspects of this direction are discussed at specialized conferences of various levels. We have previously conducted a study to determine the readiness level for the implementation of STEM technologies, particularly robotics [19]. There are separate studies related to the preparation of professionals in various fields: virtual learning in construction [18], the captain's bridges of maritime transport [24], flight simulators [2], athlete training [10], treatment and training for aiding the injured [10; 22], educating architects [21] - these are just a few examples that are already being utilized in modern training centers and educational institutions. However, the current state of implementing immersive technologies into the education system as a whole remains insufficiently researched.

The research goal: based on the analysis of global research results, to determine the state of implementation of immersive technologies in the education system and identify promising research directions.

2. MATERIALS AND METHODS

The research was conducted by us according to the following plan:

1. Determination of the purpose, key questions, and application areas.
2. Selection of the research methodology: choosing scientific databases, defining key terms and selection criteria for documents, data export; selecting tools for visualizing the data obtained and searching for visual interpretations that most clearly demonstrate key aspects of the selected data (relationships, correlations, etc.).
3. Analysis of the results obtained, formulating conclusions, and determining prospective research directions.

We were interested in the level of interest within the scientific community regarding the development of immersive technologies and the metaverse as a natural extension and combination of such technologies. A separate focus was on investigating the use of immersive technologies in education: development, implementation, best practices within the education system, and other aspects.

Interest in immersive technologies is growing. The number of scientific publications in the Scopus database using keywords «metaverse» and «immersive» has shown a significant increase over the last two years (figure 1):

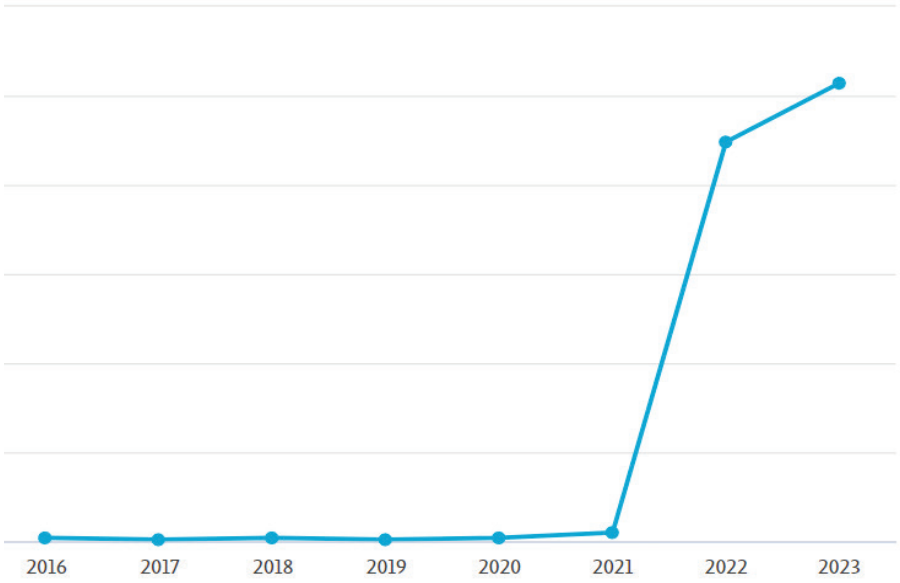

Figure 1. Number of publications in the Scopus database using keywords "metaverse", "immersive"

For the next phase of the research, we selected "immersive", "metaverse", and "education" as the key terms. The research encompassed various document types: articles, conference papers, and reports.

Scopus, the bibliographic database, was chosen for bibliographic analysis. Data selection was conducted on November 1, 2023, using the chosen keywords from 2015 to 2023. Comparative analysis was performed for 2022 and 2023. Table 1 presents the search results for the keywords "metaverse", followed by "metaverse & education":

Table 1

Documents by subject areas according to the results of the scan in all fields using the search "metaverse & education" (Source: Scopus)

Subject	2023		2022	
	Metaverse	Metaverse& Education	Metaverse	Metaverse& Education
	Number	Number	Number	Number
1	2	3	4	5
1. Computer Science	1038	192	632	103
2. Engineering	642	112	338	63
3. Social Sciences	363	117	200	42
4. Decision Sciences	208	36	130	24

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Table 1 continued

1	2	3	4	5
5. Mathematics	201	51	140	19
6. Business, Management and Accounting	190	19	56	4
7. Arts and Humanities	98	5	69	3
8. Physics and Astronomy	92	10	87	14
9. Materials Science	89	11	60	10
10. Medicine	83	22	58	19
11. Economics, Econometrics and Finance	62	4	13	0
12. Energy	62	19	50	6
13. Psychology	61	6	30	5
14. Environmental Science	45	19	28	6
15. Chemistry	26	3	15	3
16. Chemical Engineering	25	5	13	3
17. Biochemistry, Genetics and Molecular Biology	21	3	12	1
18. Health Professions	19	2	7	3
19. Earth and Planetary Sciences	15	4	15	4
20. Multidisciplinary	14	7	8	0
21. Neuroscience	7	1	12	0
22. Nursing	7	4	4	2
23. Agricultural and Biological Sciences	4	1	7	2
24. Immunology and Microbiology	1	1	0	0
Total	1606	293	911	144

As anticipated, the field of Computer Science had the most substantial number of results. In 2015, only 2 articles were found in the Scopus database using the keyword «metaverse». A significantly larger number of documents were found using the queries "immersive" and "immersive & education". There was no substantial change in the ranking of fields based on the number of documents in 2023. The search results for «immersive & education» are presented in tabl. 2:

Table 2

Documents by subject areas according to the results of the scan in all fields using the search "metaverse & education" (Source: Scopus)

Subject	2023		2022	
	Immersive	Immersive& Education	Immersive	Immersive& Education
	Number	Number	Number	Number
1	2	3	4	5
1. Computer Science	2 060	400	2181	359
2. Engineering	1 158	234	1337	240
3. Social Sciences	893	309	811	266
4. Medicine	401	129	403	86
5. Mathematics	397	87	553	0
6. Arts and Humanities	296	35	301	19
7. Physics and Astronomy	194	30	291	31
8. Psychology	193	30	230	26
9. Materials Science	160	24	136	15

Table 2 continued

1	2	3	4	5
10. Business, Management and Accounting	159	25	151	28
11. Environmental Science	102	26	120	25
12. Neuroscience	90	4	128	0
13. Energy	89	32	111	23
14. Health Professions	83	32	92	21
15. Nursing	80	37	58	30
16. Chemical Engineering	75	16	64	10
17. Multidisciplinary	67	9	45	7
18. Biochemistry, Genetics and Molecular Biology	64	8	73	14
19. Agricultural and Biological Sciences	47	13	23	6
20. Chemistry	44	2	42	6
21. Earth and Planetary Sciences	41	9	59	16
22. Economics, Econometrics and Finance	38	8	21	6
23. Immunology and Microbiology	10	2	12	2
24. Pharmacology, Toxicology and Pharmaceutics	8	4	6	2
25. Dentistry	5	4	2	1
26. Veterinary	5	2	2	0
Total	3598	791	3729	684

It's worth noting that the number of publications dedicated to researching various aspects of the metaverse significantly increased from 911 in 2022 to 1606 in the incomplete data for 2023. The number of publications concerning immersive technologies remains almost the same: 3729 in 2022 and 3598 in the incomplete data for 2023.

From the analysis of 141 documents from 2018 to 2023 based on our query, we identified a group of 39 authors involved in research in this field. Through scientific mapping using VOSviewer (1.6.20), we distinguished 7 primary authors. For each author, the overall strength of their collaborations with other authors was calculated. Authors with the highest total connection strength were filtered. Before moving to the network representation of relationships among authors, the ranking of the most frequently cited authors could be seen in the interface provided by the software, as shown in figure 2:

Selected	Author	Documents	Citations	Total link strength
☑	al ridhawi, ismaeel	1	17	4
☑	aloqaily, moayad	1	17	4
☑	bouachir, ouns	1	17	4
☑	karray, fakhri	1	17	4
☑	saddik, abdulmotaleb el	1	17	4
☑	chu, hui-chun	1	2	2
☑	hwang, gwo-jen	1	2	2
☑	tu, yun-fang	1	2	2
☑	lescop, laurent	1	1	1
☑	sopher, hadas	1	1	1
☑	dorado-diaz, ignacio p.	1	0	6
☑	luimula, mika	1	0	6
☑	pizarro-lucas, emiliana	1	0	6
☑	pyae, aung	1	0	6
☑	ravyse, werner	1	0	6
☑	sanchez, pedro l.	1	0	6
☑	thaw, aung khant	1	0	6
☑	anchna	1	0	5
☑	chen, chein-ming	1	0	5

Figure 2. Authors meeting the selection criteria with the highest citation index

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The interface was sorted by the most cited author before mapping. Figure 3 displays the map based on the "total link strength" criterion, indicating the number of publications where two key terms occur together.

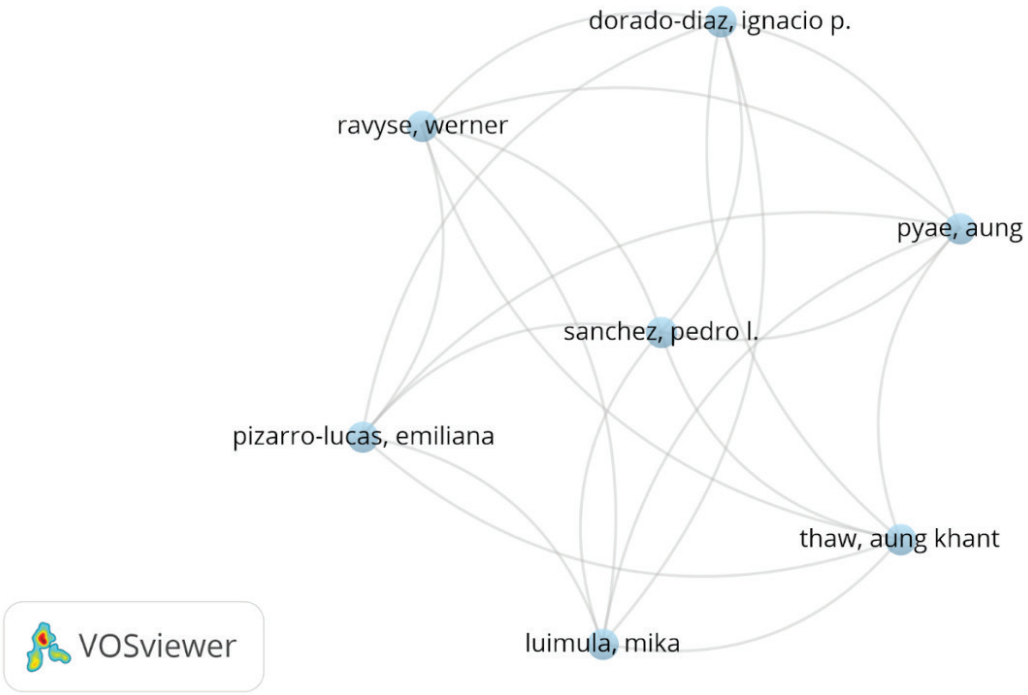

Figure 3. Authors with the highest index based on the "total link strength" criterion

For a more in-depth analysis over the past 5 years, we conducted a search using the query ["Metaverse"]&["Immersive" OR "Augmented Reality" OR "Virtual Reality" OR "Virtual Worlds" OR "Second Life" OR "Immersion virtual reality" OR "Mixed Reality" OR "Avatars" OR "Digital Twins"] & ["Education" OR "Learning" OR "E-learning"]. We found 582 documents distributed across various fields, among which 10 comprised the highest number of documents. The ten fields with the most documents found are presented in figure 4:

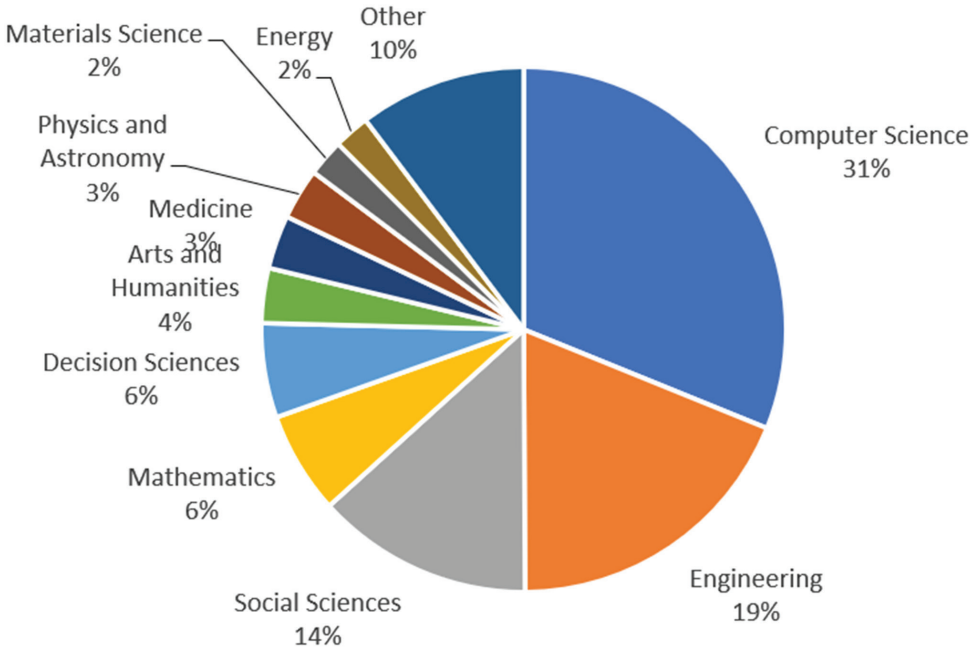

Figure 4. Top 10 fields by the percentage of relevant documents

So, in the field of computer science, 396 documents meeting the selection criteria were found; engineering – 239; social sciences – 170; mathematics – 80; decision sciences – 74; arts and humanities – 43; medicine – 42; physics and astronomy – 40; materials science – 29, and energy – 28. The first two subject areas are naturally leading in this direction, as, besides the experience of using immersive technologies and the metaverse in education, part of the research is primarily dedicated to software development, addressing technical issues, and only then exploring possibilities for use, including in the learning process.

27. FINDINGS

Based on the research conducted, groups of authors have been identified who have been involved in comprehensive studies in the field of immersive technologies and education over the last five years. Let's focus on the most significant research results that capture the state and various aspects in this defined area.

It's noteworthy that among these documents, only two articles belong to authors from Ukraine [13; 8]. Dyulicheva Yu. and Glazieva A. explored certain tools for teachers and students that enable the creation of educational games based on artificial intelligence and immersion technologies without requiring programming skills. The authors discuss their experiences using services such as Scratch with AI abilities, Metaverse Studio for AR applications development, Google AI, and others.

Authors Kryvenko I., Chalyy K. describe metaverse tools based on Microsoft solutions to provide adaptive medical informatics education considering modern technologies. As observed, the issue of applying immersive media in Ukrainian educational institutions has not found sufficient reflection in international scientific publications. It's also important to note that a search was conducted in the Scopus database using the query "metaverse" AND "education" AND "immersive" AND "systematic" AND "review" AND "Ukraine", yielding no results. Similarly, the query "Ukraine" AND "education" AND "immersive" AND "review" found three documents, specifically collections from thematic scientific conferences such as the eighth and ninth "Workshop on Cloud Technology in Education" (2020, 2022), "AREdu 2021 – Immersive technology today" (2021).

Among the articles dedicated to the content analysis of the research problem, there are significant studies such as [10]. The authors conducted an analysis of 32 studies focusing on the use of augmented reality. Their findings concluded that science, humanities, and arts in the education sector were the areas where augmented reality was predominantly applied. However, within the fields of healthcare, social welfare, education (including teacher training), and agriculture, there was the least representation of studies in this domain. Augmented reality was predominantly employed in education for student motivation, particularly within early childhood education and vocational training (Vocational Educational Training (VET)).

In another study [12], the authors systematically analyzed 28 publications to explore the general characteristics of augmented reality applications in STEM education. They identified that augmented reality is predominantly used in the teaching and learning process of subjects like physics, mathematics, chemistry, astronomy, and overall natural sciences. The authors noted a positive trend in studying disciplines using augmented reality. However, they highlighted a series of problematic issues, including technical problems, usability, cost, and the specific nature of the environment.

Another research paper [20] accentuates the changing role of the metaverse in societal understanding. The authors emphasize the shift in paradigm from the concept of the metaverse as a second life to a new vision – where the metaverse is a social value for the new generation. This change primarily results from the integration of mobile devices and digital data into everyday life. Blockchain, cryptocurrencies, non-fungible tokens (NFTs), and social networks have become functionally necessary and socially significant. The authors conduct an analysis of three metaverses (Metaverse Ready Player One, Roblox, and Facebook) regarding hardware, software, and content. The question of problems and advantages of learning in the metaverse compared to traditional education and the potential consequences of learning in the metaverse is addressed in an article [11], prepared based on the outcomes of conducting four workshops on learning in the metaverse using virtual reality.

Authors of [5] analyzed the key trends in Metaverse research and conducted an in-depth bibliometric analysis. They explored the scholarly landscape of Metaverse research, focusing on comparing tools for such analysis. Their findings revealed that these two tools (Bibliometrix and VOSviewer) yield good results for studying frequency data across multiple documents to form a network of connections between keywords, identifying and highlighting the primary research trends in the Metaverse field. Additionally, they determined that the most common themes in articles about the metaverse were computer science, engineering, and social sciences. Keywords related to virtual reality (VR), augmented reality (AR), blockchain, and the Internet of Things (IoT) were frequently used. Recent publications were also concentrated on machine learning, deep learning, and digital twins.

A detailed analysis of the content of the articles was conducted in the work of [27], which focused on the study of practical use cases and potential advantages of XR in workplace collaboration. Authors utilized the PRISMA protocol to analyze publications from 2009 to 2020. They scrutinized approximately two hundred scientific articles, through which they identified three primary areas of XR application: design, remote collaboration, and learning. Additionally, the authors delved into issues regarding software for augmented reality world formation. The research identified directions in XR studies: collaboration, work practices, and knowledge transfer assessment. It was determined that the primary applied research methods in publications were traditional and included interviews and observations. The authors highlighted the infrequent use of ethnography in research, although it has the potential to aid in understanding the social and material aspects of work in real working conditions.

Systematic review of 41 studies published from 2011 to 2022 in databases such as ACM Digital Library, Emerald, Google

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Scholar, IEEE, ScienceDirect, Springer, Taylor and Francis Online, and Wiley Online Library was conducted in study [3]. The search was conducted using keywords "Metaverse" or "Augmented Reality" or "Virtual Reality" or "Virtual Worlds" or "Second Life" or "Immersion virtual reality" & or "Mixed Reality" or "Avatars" or "Digital Twin" & ["Education" or "Learning" or "E-learning"] & ["Students" or "pupil" or "learner"] & ["technology adoption" or "technology acceptance"]. Their analysis confirmed that the primary methods of data collection are surveys, interviews, and experiments. It was also found that the majority of works do not have a specific subject area. Among the dominant fields are computer science, medicine, pilot training, and tourism education. It was also found that most Metaverse studies (83%) are conducted in higher education institutions, fewer in school education. The authors attribute this to the target audience of academic teaching of professional skills – students and postgraduates. The frequency characteristics of factors such as "Social impact/subjective norm, expected productivity, expected effort duration, favorable conditions, imagined pleasure, self-efficacy, immersion, imagined compatibility, user satisfaction, imagination, interaction, imagined anxiety, and personal innovativeness" are the most observed factors that have successfully influenced the acceptance and adjustment of virtual reality. One of the factors indicating the importance of making decisions about the application of such technologies is the relevance of synchronous or asynchronous learning.

Systematic review of 41 studies published from 2011 to 2022 in databases such as ACM Digital Library, Emerald, Google Scholar, IEEE, ScienceDirect, Springer, Taylor and Francis Online, and Wiley Online Library was conducted in study [3]. The search was conducted using keywords "Metaverse" or "Augmented Reality" or "Virtual Reality" or "Virtual Worlds" or "Second Life" or "Immersion virtual reality" & or "Mixed Reality" or "Avatars" or "Digital Twins" & ["Education" or "Learning" or "E-learning"] & ["Students" or "pupil" or "learner"] & ["technology adoption" or "technology acceptance"]. Their analysis confirmed that the primary methods of data collection are surveys, interviews, and experiments. It was also found that the majority of works do not have a specific subject area. Among the dominant fields are computer science, medicine, pilot training, and tourism education. It was also found that most Metaverse studies (83%) are conducted in higher education institutions, fewer in school education. The authors attribute this to the target audience of academic teaching of professional skills - students and postgraduates. The frequency characteristics of factors such as "Social impact/subjective norm, expected productivity, expected effort duration, favorable conditions, imagined pleasure, self-efficacy, immersion, imagined compatibility, user satisfaction, imagination, interaction, imagined anxiety, and personal innovativeness" are the most observed factors that have successfully influenced the acceptance and adjustment of virtual reality. One of the factors indicating the importance of making decisions about the application of such technologies is the relevance of synchronous or asynchronous learning.

The summary article [26] constructs a taxonomy to characterize the metaverse as a guide for classifying metaverse services. The authors identified 4 layers, 10 dimensions, and 35 characteristics of the metaverse. The first level (platform) focuses on user immersion and application in the virtual world. The second level explores the virtual representation of people or digital twins. The third level contains the necessary technology and infrastructure for the functioning of the metaverse. The last level provides blockchain services such as asset tokenization and crypto services.

The discussion on the concept of the metaverse and its creation became possible due to powerful computational solutions, the development of cloud services, and access to vast amounts of open data. The impetus for their development was the quarantine restrictions in 2020 due to COVID-19. As a result, several major companies, such as Microsoft (January 2022) and Facebook (November 2021), announced intensified work on metaverse platforms for virtual communication and interaction. According to research conducted by Microsoft [1], European companies view IT technologies as factors for business and economic development. Examples include new e-business models, trade, digital currencies, and e-learning. The use of technologies is directly linked to changes within companies and the training of qualified professionals. Currently, educational programs for a 3-year professional training in design for immersive media (GiM) are being developed in the European space [9].

The question of using such technologies in education is controversial in educational discussions since the cost and labor investment in content creation are currently greater than the benefits these technologies provide. However, society aims to create simpler interaction models with the real world and enhance existing processes through content visualization using technological advancements. Moreover, "with the growth of investments in the metaverse, the necessary hardware and software become more powerful and cheaper, and technology firms have high expectations for this market" [17].

Researchers note that the broad range of metaverse possibilities, including the virtual space offering real representations, possibly enhances the social aspect of teaching and learning, leading to growing interest among educators in this technology [25]. Furthermore, according to the results of research [14; 15; 25], the current generation of students and learners is significantly more inclined to use technology in the educational process. Generation Z (the new generation of "Virtual Natives") is more focused on artificial intelligence compared to Generation X or Y. It is important to realize that one of the education system's tasks is to instill critical thinking and responsible use of technologies by future professionals. Technologies can positively influence the formation of professional competence, provided their usage is free from abuse in the education process, such as artificial intelligence.

A significant issue is investigating teaching scenarios. Ahmed Tlili and others note that "there have been very few studies dedicated to mobile learning, hybrid learning, and micro-learning. Moreover, no studies have focused on the use of the Metaverse in education for students with disabilities" [25, p. 1].

According to researchers, using the metaverse can expand

learning opportunities by organizing practical education through scenarios that are not accessible in the physical world. This allows students to gain experience and feel the relevance of the studied theory, combining creativity, educational, and real experiences. Implementing these scenarios in higher education could entirely change how traditional courses in mathematics, physics, or chemistry are developed and taught [7, p. 36-37].

Studies conducted in collaboration between university professors, industry entrepreneurs, non-governmental organizations, and students allowed for the formation of an interactive two-way conceptual model in an immersive environment [16]. Researchers have identified social-cognitive factors of influence: collective activities enhance socialization, engaging 4-D/5-D visualization facilitates participant involvement, gamification and experience of STEM/IoT form empathetic knowledge and moral consciousness through internalization, externalization, and socialization.

28. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The analysis of scientific publications has confirmed a steady growth in the interest of researchers in immersive technologies, not only in technical aspects but also in their use in the educational process. There's an observed increase in the number of publications dedicated to the metaverse, while the number of publications about immersive technologies remains almost unchanged. Moreover, there's an expansion of subject areas in which these technologies are being used. The international academic community presents systematic research on immersive technologies in education, particularly in the metaverse, dedicated to:

1. Application areas: collaboration, work practices, and knowledge transfer evaluation.
2. Exploring the advantages over traditional learning, the drawbacks, and risks.
3. Developing real-world experiences to solve problems.
4. Investigating the disciplines in which immersive technologies are applied and finding effective ways to use them.
5. Identifying the optimal conditions and age categories for using these technologies.
6. Analyzing metaverse content and comparing their functional capabilities.
7. Exploring the underlying technologies in the metaverse (Metaverse, VR, AR, MR, XR, AI, Cloud computing, Blockchain, NFT, deep learning, digital twins, I4.0, IoT, machine learning, IoT).
8. Analyzing applications and devices.

However, each of these aspects requires further development, scaling best practices for future professionals in different fields, educational levels, and age categories. Metaverse technologies are rapidly evolving, with an increasing number of technical and software solutions whose costs are decreasing, posing one of the barriers to their widespread use, especially in the education system.

The implementation of immersive technologies in the education system could result in a decrease in the number of students who drop out due to the educational process not meeting their expectations, improving the quality of vocational training by using convenient technologies for students and providing a deeper «immersion» in future professions and acquiring professional experience.

Further research is needed on the models for structuring the educational process for various professionals, especially future teachers. It was also noted that the Ukrainian experience in using immersive technologies in the education system is insufficiently represented in the international academic community. Assessing the state of implementing these technologies in Ukraine's education system requires further research.

References

1. *A Guide to the Future. How companies across industries in Central and Eastern Europe approach the digital revolution*. (2023). Retrieved from https://info.microsoft.com/rs/157-GQE-382/images/CE-DIGTRNS-CNTNT-content-MGC0002953.pdf?fbclid=IwAR3KneHK5XFXMYpGzp1Wmjz_UZ3E8V5O_XMabaHLSUNwZwUaoHHNtIYEwBU.
2. Albeaino, G., Eiris, R., Gheisari, M., & Issa, R. R. (2022). DroneSim: a VR-based flight training simulator for drone-mediated building inspections. *Construction Innovation*, 22, 4, 831-848. DOI: 10.1108/CI-03-2021-0049.
3. Alfaisal, R., Hashim, H., & Azizan, U. H. (2022). Metaverse system adoption in education: a systematic literature review. *Journal of Computers in Education*, 11, 259-303. Retrieved from https://link.springer.com/article/10.1007/s40692-022-00256-6.
4. Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Educational Technology & Society*, 17, 4, 133-149. Retrieved from https://www.jstor.org/stable/jeductechsoci.17.4.133
5. Brahimi, T., & Haneya, H. (2023). Mapping the Scientific Landscape of Metaverse Using VOSviewer and Bibliometrix. *2023 20th Learning and Technology Conference (L&T)*. IEEE. Retrieved from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://repository.effatuniversity.edu.sa/bitstream/handle/20.500.14131/751/Dr_Tayeb_Manuscript_Metaverse_Feb_19.pdf?sequence=1&isAllowed=y
6. De Felice, F., Petrillo, A., Iovine, G., Salzano, C., & Baffo, I. (2023). How Does the Metaverse Shape Education? A Systematic Literature Review. *Applied Sciences*, 13, 9, 5682. DOI: 10.3390/app13095682.
7. Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Vigla, G., & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, Opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 66, 102542, 2-55.
8. Dyulicheva, Y. Yu., & Glazieva, A. O. (2022). Game based learning with artificial intelligence and immersive technologies: an overview. *CEUR Workshop Proceedings*, 3077, 146-159.
9. Gestalter/-in für immersive Medien (ab August 2023) IHK Berlin. Retrieved from https://www.ihk.de/berlin/ausbildung/ausbildungsberufe-von-a-bis-z/gestaltung-immersive-medien-5688836. Accessed on: 10.11.2023.
10. Giljarhus, K. E. T., Liland, F. F., & Oggiano, L. (2023). Virtual skeleton methodology for athlete posture modification in CFD simulations. *Sports Engineering*, 61, 2, 39. Retrieved from https://www.researchgate.net/publication/373542508_Virtual_skeleton_methodology_for_athlete_posture_modification_in_CFD_simulations. Accessed on: 2.11.2023. DOI: 10.1007/s12283-023-00430-8.
11. Hines, P., & Netland, T. H. (2023). Teaching a Lean masterclass in the metaverse. *International Journal of Lean Six Sigma*, 14, 6, 1121-1143.
12. Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers and Education*, 123, 109-123. Retrieved from http://www.journals.elsevier.com/computers-and-education/. DOI: 10.1016/j.compedu.2018.05.002.
13. Kryvenko, I., & Chalyy, K. (2023). Phenomenological toolkit of the metaverse for medical informatics' adaptive learning. *Educacion Medica*, 24, 5, 100854. DOI: 10.1016/j.edumed.2023.100854.

№ 5 (218) 2024
ISSN 2522-9729 (online)

14. Kushnir, N., Manzhula, A., & Valko, N. (2013). Bridging the Generation Gap in ICT Education. *Communications in Computer and Information Science*, 412 CCIS, 229-251.
15. Kushnir, N., Manzhula, A., & Valko, N. (2013). New approaches of teaching ICT to meet educational needs of net students generation. *CEUR Workshop Proceedings*, 1000, 195-208.
16. Kwok, P. L., Chen, J. K.-N., & Fung, J. T.-C. (2022). Two-way knowledge transfer among university academics, young entrepreneurs, NGOs and students in STEM and IoT metaverses: Conceptual model, research agendas and contextual challenges. *Proceedings of the 30th International Conference on Computers in Education, ICCE 2022*. Asia-Pacific Society for Computers in Education.
17. Mogaji, E., Wirtz, J., Belk, R. W., & Dwivedi, Y. K. (2023). Immersive time (ImT): Conceptualizing time spent in the metaverse. *International Journal of Information Management*, 72, 102659. DOI: 10.1016/j.ijinfomgt.2023.102659.
18. Ogunseiju, O. R., Akanmu, A. A., Bairaktarova, D., Bowman, D. A., Jazizadeh, F. (2023). Assessment of interactive holographic scenes in learning applications of sensing technologies in construction education. *Journal of Civil Engineering Education*, 149, 4, 04023007. Retrieved from https://ascelibrary.org/doi/abs/10.1061/JCEECD.EIENG-1899. Accessed on: 4.11.2023.
19. Osadchyi, V., Valko, N., & Kushnir, N. (2019). Determining the level of readiness of teachers to implementation of STEM-education in Ukraine. *ICT in Education, Research and Industrial Applications: Integration, Harmonization and Knowledge Transfer: proceedings of the 15th International Conference ICTERI 2019*. (Vol. 2393). Kherson. Retrieved from http://ceur-ws.org/Vol-2393/paper_369.pdf. Accessed on: 7.08.2023.
20. Park, S.-M., & Kim, Y.-G. (2022). A metaverse: Taxonomy, components, applications, and open challenges. *IEEE Access*, 10, 4209-4251. DOI: 10.1109/ACCESS.2021.3140175.
21. Patel, P., & Khan, S. (2023). Review on virtual reality for the advancement of architectural learning. *2023 IEEE Renewable Energy and Sustainable E-Mobility Conference, RESEM 2023*. Retrieved from https://ieeexplore.ieee.org/document/10236123. Accessed on: 24.10.2023. DOI 10.1109/RESEM57584.2023.10236123.
22. Rabotin, A., Glick, Y., Gelman, R., Fink, N., & Furer, A. (2023). Practicing Emergency Medicine in the Metaverse: A Novel Mixed Reality Casualty Care Training Platform. *Surgical Innovation*, 30, 5, 586-594. DOI: 10.1177/15533506231191576.
23. Sarıtaş, M. T., & Topraklıkoğlu, K. (2022). Systematic literature review on the use of metaverse in education. *International Journal of Technology in Education (IJTE)*, 5, 4, 586-607. DOI: 10.46328/ijte.319.
24. Templin, T., Popielarczyk, D., & Gryszko, M. (2022). Using augmented and virtual reality (AR/VR) to support safe navigation on inland and coastal water zones. *Remote Sensing*, 14, 6, 1520. DOI: doi.org/10.3390/rs14061520.
25. Tlili, A., Huang, R., Shehata, B., & Liu, D. (2022). Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis. *Smart Learning Environments*, 9, 1, 1-31.
26. Vaghani, A., Gürpinar, T., & Große, N. A (2022). Taxonomy Characterizing Blockchain-Empowered Services for the Metaverse. In S. Y. Yurish (Ed.), *Proceedings of the 2022 International Conference on Emerging Trends in Information Technology and Engineering. IEEE*. Retrieved from https://www.researchgate.net/publication/365316933_A_Taxonomy_Characterizing_Blockchain-Empowered_Services_for_the_Metaverse
27. Vasarainen, M., Paavola, S., & Vetoshkina, L. (2021). A Systematic Literature Review on Extended Reality: Virtual, Augmented and Mixed Reality in Working Life. *International Journal of Virtual Reality*, 21, 2, 1-28. DOI: 10.20870/IJVR.2021.21.2.4620.

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