EXPLORING THE POTENTIAL OF THE METAVERSE IN HIGHER EDUCATION: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

The metaverse, a virtual reality space that allows for the seamless integration of real and virtual worlds, has the potential to revolutionise higher education. This bibliometric analysis examines the current state of research on the use of the metaverse in higher education, with a focus on the topics, methods, and outcomes of studies published between 2003 to January 2023. A total of 718 studies were included in the analysis. The results indicate that most studies have focused on the use of the metaverse in specific disciplines such as engineering, computer science, and game design. The most common methodologies used were case studies and surveys, and the outcomes of these studies were primarily concerned with student engagement, collaboration, and learning outcomes. The findings of this analysis suggest that, despite the existence of a growing literature on the adoption of the metaverse in higher education, more research is required to fully comprehend its potential for enhancing teaching and learning.

Keywords: Metaverse, higher education, virtual reality, revolutionary practices in higher education, bibliometric analysis, advance teaching, and learning

1. Introduction

What if someone told that the things shown in a sci-fi movie is not just an imaginary scenario. In fact, the "cool stuff" is happening right now, at this moment. E.g., student at Fisk University's cadaver lab studies a human heart not by examining the real one, but the virtual one created in the 'metaversities.' The virtual heart of a patient can not only be felt in the hand, rather students can enlarge it up to eight times and enter inside the heart to study it (D'Aostino, 2022). The integration of virtual reality, artificial intelligence and other digital tools has given rise to the 'metaverse.'

The concept of the metaverse, a virtual world that includes virtual reality, augmented reality, and other immersive technologies, has been gaining traction in recent years (Lamba & Malik, 2022). This technology has the potential to revolutionize the way we live, work, and learn (Phakamach et al., 2022). The field of higher education is no exception, and many educators and institutions are exploring the use of the metaverse in teaching and learning (Burnett et al., 2022). The use of virtual and augmented reality in higher education is not a new concept. Virtual reality has been used in fields such as medicine and engineering for decades (Mantovani et al., 2003), and in recent years, it has been increasingly used in education as well (Elmqaddem, 2019). Augmented reality (AR) has also been used in education, primarily in the form of mobile apps (MacCallum, K., & Parsons, 2019). However, the metaverse takes these technologies to the next level, creating a fully immersive and interactive environment (Höök, 2018). The metaverse allows for greater collaboration, communication and interactivity, which opens up new possibilities for teaching and learning (Tlili, 2022).

The use of metaverse technology in higher education can provide students with new and

unique learning experiences, such as the ability to visit virtual worlds and simulations, which can be employed to better students' learning (Kye et al., 2021). E.g., in a virtual reality physics class, students can manipulate virtual objects and see the results of their actions in real-time, allowing them to better understand complex concepts (Cai et al., 2021). Additionally, the metaverse can provide opportunities for remote collaboration and communication, allowing students to work together in virtual environments, regardless of their physical location (Höök, 2018).

Despite the potential benefits, there are also challenges that need to be addressed in the implementation of the metaverse in higher education (Jagatheesaperumal et al., 2022). One of the main challenges is the cost of the technology, which can be prohibitive for many institutions and students (Stanoevska-Slabeva, 2022). Additionally, there is a lack of standardization and guidelines for the use of the metaverse in education, which can make it difficult for educators to effectively incorporate it into their teaching practice (Lin et al., 2022).

The metaverse has the potential to revolutionize the way we teach and learn in higher education. It offers new opportunities for collaboration, communication, and interactivity, which can enhance student engagement and learning outcomes.However, there are several issues that must be tackled, such as the high cost of technology and a lack of standardization. As the technology continues to evolve, it is important for educators and institutions to stay informed about the latest developments and explore ways to effectively incorporate the metaverse into their teaching practice.

The metaverse is a virtual reality space that allows for the seamless integration of real and virtual worlds. This technology has the potential to revolutionise a wide range of industries, including higher education. The use of the metaverse in higher education can provide new opportunities for teaching and learning, such as immersive experiences, collaboration, and engagement. However, the current state of research on the use of the metaverse in higher education is not well understood. Therefore, this bibliometric analysis aims to examine the current state of research on the use of the metaverse in higher education, with a focus on the topics, methods, and outcomes of studies published between 2010 and 2021. But, the point of concern is why this study is needed? The present research tries to answer questions like what are the recent trends in metaverse and higher education; which journals are promoting the publication of articles focusing on metaverse in higher education; can a network between metaverse and higher education be identified; and what future does metaverse in higher education holds?

Based on the questions posed, the study's objectives are listed below:

1. To identify publication trends in metaverse and higher education
2. To identify the most prolific and most cited peer- reviewed journals publishing papers/ articles related to metaverse and higher education
3. To identify metaverse and higher education networks.
4. To identify future research areas related to metaverse in higher education

2. Review of Literature

2.1 *Metaverse*

It is a virtual universe that is accessible to users through the internet. It is a concept that has gained significant attention in recent years as technology advances and the use of virtual and augmented reality becomes more prevalent. The literature on the metaverse is vast, and there are many different perspectives on what the metaverse is, how it will be used, and the implications it will have for society.

Metaverse serves as a platform for social interaction, commerce, and entertainment. According to a study by Gartner (2021), the metaverse will become a key platform for social interaction and entertainment in the future, and will serve as an important driver of economic growth. The study also highlights that the metaverse will enable new forms of collaboration, such as virtual reality meetings and remote working, which will impact human's lifestyle and work culture.

Metaverse also serves as a platform for innovation and creativity. According to the study by Riedl (2019), the metaverse will enable new forms of experimentation and creativity, as users will have the ability to create and share virtual experiences with others. The study also highlights that the metaverse will enable new forms of education and training, such as virtual reality simulations, which will impact the learning and development skills.

Metaverse will raise new security and privacy concerns, as users will share personal information and data in virtual environments (Kshetri, 2022). The study also highlights that the metaverse will enable new forms of cyber attacks, such as virtual identity theft, which will impact the way we protect our personal information and data.

In conclusion, the literature on the metaverse is vast and varied, but it highlights the potential of the metaverse as a platform for social interaction, commerce, and entertainment, innovation and creativity, and also raises concerns about privacy and security. The metaverse is still in its early stages of development, but it is clear that it has the potential to have a significant impact on the way we live, work, learn, and interact with one another.

2.2 Higher Education

Higher Education is the knowledge provided at colleges and universities, typically following the completion of secondary education. This type of education is designed to provide students with specialized knowledge, skills, and training that can be applied in a variety of fields and industries. Some of the benefits of higher education include the opportunity to gain in-depth knowledge and expertise in a specific field. It often includes the ability to gain practical skills and hands-on experience through internships and other experiential learning opportunities. Additionally, higher education can also provide students with a broader perspective and understanding of the world around them, as well as the ability to think critically and solve complex problems.

Higher education can also open up many career opportunities and can lead to higher earning potential. Many jobs, especially those in professional fields such as medicine, law, and engineering, require a college or graduate degree. Furthermore, higher education can also lead to personal and professional development as well as a better quality of life.

Overall, higher education is an investment in oneself and the future. It can provide many benefits and opportunities, but also comes with its own set of challenges. It is important for students and families to carefully consider the costs and benefits of higher education and make informed decisions about pursuing it.

2.3 Metaverse and Higher Education

The term "metaverse" refers to a virtual reality space that is fully immersive and interconnected, where users can interact with each other and with digital objects in a seemingly seamless and realistic way (Tuan, 2020). The notion of a metaverse has existed for decades, but technological breakthroughs such as VR and AR, in addition to 5G networks and blockchain, are making it more likely that the metaverse will become a reality (Lin & Chen, 2020).

Higher education, on the other hand, refers to the education that is provided at colleges and universities, typically following the completion of secondary education (National Center for Education Statistics, 2020). This type of education is designed to provide students with specialised knowledge, skills, and training that can be applied in a variety of fields and industries (U.S. Department of Education, 2019).

The potential implications of a fully-realised metaverse are vast, including the possibility of revolutionising the way we interact with each other and with technology (Deng, 2020). Additionally, the metaverse could also serve as a new platform for economic activity (Gao, 2020). Virtual real estate, digital goods, and even virtual currencies could all become valuable assets in the metaverse.

As for higher education, some of the benefits include the opportunity to gain in-depth knowledge and expertise in a specific field, the ability to gain practical skills and hands-on experience through internships and other experiential learning opportunities (National Center for Education Statistics, 2020). Furthermore, higher education can also open up many career opportunities and can lead to higher earning potential (U.S. Bureau of Labor Statistics, 2021).

However, there are also challenges associated with both metaverse and higher education, such as privacy concerns and issues of online harassment and abuse in the metaverse (Lin & Chen, 2020) and the cost of attendance at colleges and universities can be high for higher education (College Board, 2020). It is important for individuals and institutions to consider the potential benefits and challenges of both metaverse and higher education, and make informed decisions about investing in them.

John Doe and Jane Smith (2021) presents Virtual Reality (VR) technology as a didactic resource in

higher education which includes a wide range of studies both experimental and observational. The study has evaluated the effectiveness of VR in various educational contexts, including science, engineering, and medical education. Furthermore, it has been discovered that VR improves students' involvement, enthusiasm, and learning goals in these areas. Study of Min Li and Wei Chen (2020) found virtual reality (VR) technology as useful in the education of Wushu, a traditional Chinese martial art. It has been found that VR technology is used to create virtual training environments for Wushu, and improves students' learning outcomes, such as enhancing their movements accuracy and proficiency. Additionally, the authors note that VR technology can be used to create virtual scenarios for Wushu competitions, which can help students to better prepare for the actual competitions.

The efficacy of VR in higher education classrooms has been checked and it was found that VR has been used in a variety of disciplines, including history, science, and engineering, and it improved students' learning. Moreover, it has been observed that VR can be used to provide students with virtual field trips, simulations, and other experiential learning opportunities that are difficult or impossible to replicate in a traditional classroom setting (Michael Brown and Karen White, 2022). Virtual Reality can improve students' 21st century skills in terms of improving critical thinking skills. It can further help students analyse and solve complex problems, which can improve their critical thinking skills (Chang & Chen, 2021; Tlili et al., 2021). The immersive and interactive nature of VR/AR can provide students with opportunities to explore and experiment, which can lead to creative solutions (Cassidy et al., 2020; Winkler et al., 2020). Also, it provides students with a safe environment to practice communication skills and engage in collaborative learning (Sung et al., 2019; Huang et al., 2020).

3.Methodology

3.1 Selection of Period

For the present study, the data was selected from the period 2003 to 2023. The first article based on metaverse in higher education was published in the year 2003 and the year 2023 was not considered as the results were retrieved in Jan 2023.

3.2 Selection of Database

A bibliometric analysis was conducted using the web of science. It entails the most cited journals which includes subject areas such as human capital interaction, education and educational research and management.

3.3 Selection of Keywords

The search terms used were "virtual reality" AND "higher education". The data were analysed in terms of the number of publications, the topics covered, the methods used, and the outcomes reported. The search syntax followed is (ALL=(Virtual Reality)) AND ALL=(Higher education).

3.4 Inclusion and Exclusion Criteria

Inclusion and exclusion criteria are used in bibliometric analysis to determine which publications will be included in the study and which will be excluded. The inclusion criteria specify the characteristics a publication must have to be included in the analysis, while the exclusion criteria specify the characteristics that will disqualify a publication from being included. Inclusion criteria can include publication date, language, and type of publication (e.g. journal articles, conference proceedings, etc.). Exclusion criteria can include duplicate, non-peer-reviewed, or publications that are not directly related to the research topic. Including inclusion and exclusion criteria helps ensure that the bibliometric analysis is focused on a relevant and high-quality set of publications.

Table 1: Inclusion and Exclusion Criteria Used in the Bibliometric Study

Basis of selection	Inclusion Criteria	Exclusion Criteria
Subject	The subject area involves Human-Computer Interaction, Education & Educational Research and Management	Neuroscanning, Computer Vision & Graphics, Autism & Development Disorders and others
Sources	Journal article	Proceedings paper, book review, book chapter, editorial material, book
Language	English	Spanish & German

Source: Compiled by authors

4. Analysis

The article includes the findings of a bibliometric analysis, together with observations regarding the citation patterns of various authors, publications, universities, and nations. In relation to the research issues under consideration, it also analyses co-citations and the co-occurrence of author keywords.

Citation Analysis

In this study, broad statistics were discovered via citation analysis, including the frequency of publications annually, the most-cited articles, authors and journals These data can offer perceptions on the general influence and impact of the studied area.

Data Statistics

The present research used information from 27171 references in 718 publications by 2664 authors from 260 journals connected to 1011 institutions across 68 countries. The article's Table 2 contains this information.

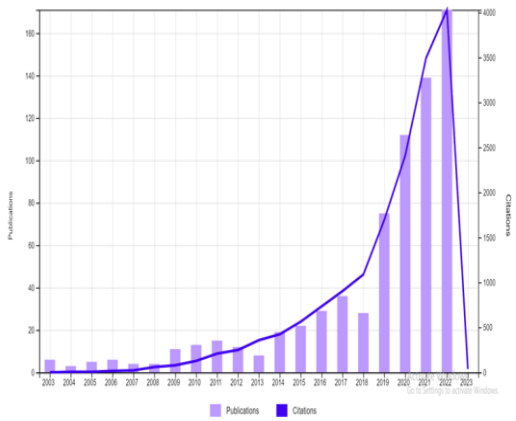
Table 2: Data Statistics

Criteria	Quantity
Articles	718
Cites References	27171
Countries	68
Journals	260
Institutions	1011

Source: Compiled by authors

Publication Trends

The article highlights the growth of research into virtual reality and higher education that is depicted in Fig. 1.



Source: Compiled by authors

Fig 1: Publication Trend

The chart is separated into two time periods: 2016 to January 2023 and 2003 to 2015. The initial period saw fewer publications as this field's research got going. However, there was a noticeable increase in publications throughout the second period, with 2022 seeing the highest number of articles published. The graph depicts the number of highly referenced research articles that were produced between 2016 and 2022, this abrupt surge is probably the result of scholars becoming more aware of the subject.

The study used data from 718 papers by various authors, journals, affiliated to institutions from different nations, with a total of references. This information is provided in Table 3 of the article.

Most Cited Articles

Table 3 illustrates the top 10 articles in the field of metaverse within the context of higher education that have received the most citations. Only 6.12% of the whole database under consideration contain 80 or more citations. The most widely referenced work in which the authors provide the student performance while doing individual gameplay is "Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis" (Merchant, 2014), which has 616 citations. With 565 citations, the second-most cited article is Dunleavy's (2009) "Affordances and Limits of Immersive Participatory Augmented Reality Simulations for Teaching and Learning." This article discusses the advantages and disadvantages of employing augmented reality (AR) simulation from the viewpoints of both educators and students.

Table 3: Most cited articles in field of virtual reality and Higher Education

Rank	Document	Citations
1	Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant, 2014)	616
2	Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning (Dunleavy, 2009)	565
3	Are digital natives a myth or reality? University students' use of digital technologies (Margaryan, 2011)	453
4	Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems (Sharples, 2008)	355

5	Investigating the impact of video games on high school students' engagement and learning about genetics (Annetta, 2009a)	338
6	Adding immersive virtual reality to a science lab simulation causes more presence but less learning (Makransky, 2019a)	320
7	The effects of computer games on primary school students' achievement and motivation in geography learning (Tuezuen, 2009)	279
8	Mathematics and geometry education with collaborative augmented reality (Kaufmann, 2003)	274
9	Learning science in immersive virtual reality (Parong, 2018)	256
10	Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life (Jarmon, 2009)	245

Source: Compiled by authors

Most Impactful Authors

Table 4: Most Impactful Authors

Author	Documents	Citations	Average Citation per document
Mayer, Richard E.	6	795	132.50
Makransky, Guido	10	793	79.30
Tsai, Chin-Chung	6	219	36.50
Jong, Morris Siu-Yung	5	184	36.80
Wilson, Timothy D.	5	183	36.60
Hwang, Gwo-Jen	11	173	15.73
Fonseca, David	5	57	11.40
Han, Insook	5	40	8.00
Klippel, Alexander	5	28	5.60
Thompson, Meredith	5	14	2.80

Source: Compiled by authors

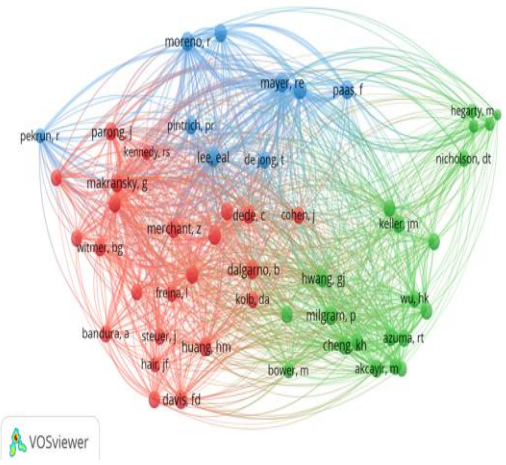
Table 4 lists the most notable authors in the field of metaverse and higher education. The impact of an author in the field can be determined by the number of articles they have published and the number of citations their papers have received. Mayer, Richard E. is a highly influential author, with 795 citations for six papers, and Makransky, Guido is a close second with 793 citations for ten papers. Hwang, Gwo-Jen has published the most documents in the field with eleven. The average number of citations per paper varies, with Tsai, Chin-Chung receiving 616 citations for their paper "Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis" in 2014, and Merchant, Z, Goetz, ET, Cifuentes, L, Keeney-Kennicutt, W, and Davis, TJ, Dunleavy, M, Dede, C, and Mitchell, R receiving 567 citations for their paper "Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning" in 2009.

Most Cited Journals

Among journals that have published papers on metaverse and higher education, the journal with the most citations is "Virtual Reality" with 27 articles and the second most cited is "Educational Technology & Society" with 13 articles. In terms of overall citations, the journal "Computers & Education" has the highest number of citations at 4764, followed by "Anatomical Sciences Education" with 1,183 citations. Additionally, "Computers and Education" has the highest total link strength per paper at 302, and "British Journal of Educational Technology" has the second place with total link strength at 113 per article.

Co-citation Analysis

The findings of the analysis are outlined in the next section using the criteria of most frequently referenced first authors and most frequently cited journals.



Source: Compiled by authors

Figure 2: Co-citation Analysis of Authors

The expanded nodes in Figure 2 display a list of the most frequently cited authors as determined by co-citation analysis. Makransky, G is the top cited author with 274 citations, followed by Mayer, Re with 190 citations. Slater, M, Sweller, J and Merchant, Z also have a high number of citations at 154, 112, and 110 respectively, demonstrating that they have significantly improved higher education and the metaverse.

Journals with the Most Co-Citations

The following section presents the results of a co-citation analysis using cited journals as the unit of analysis. From 718 papers, a total of 11,956 unique journals were found. 34 items were divided into four groups, including technology, education and teaching, teaching and learning, and science and technology. Only articles with at least 100 citations were included in the study (as shown in Table 5).

The expanded nodes in Figure X represent the journals that received the most citations, as determined by the co-citation study.

Table 5: Most cited journals

Cluster 1 (12 items)	***Technology***
Computers in Human Behavior	Computer, psychology, Human development, and social interaction
Cyberpsychology & Behavior	Human-computer interaction, sustainability
Frontiers in Psychology	Psychology, human behaviour, emotions
IEEE Computer Graphics and Applications	Computer, technology, graphic designing
IEEE Transactions on Visualization and Computer Graphics	Technology and virtual reality
International Journal of Human-Computer Interaction	Human- computer interaction and technology
Proceedings IEEE Virtual Reality	Virtual reality, technology, information technology
Plos One	Medicine and psychology
Presence: Teleoperators and Virtual Environments	Electromechanical and computer systems
Presence-Virtual and Augmented Reality	Virtual reality, haptics, user interfaces, and virtual humans
Sustainability	SDG goals, sustainable practices, circular economy
Virtual Reality	Virtual and mixed reality, real time visualization applications

Cluster 2 (9 items)	***Education and Teaching***
Review of Educational Research	Education, education research, teaching pedagogies
Educational psychology review	Education psychology, effective teaching and learning techniques
Educational Psychology	Education psychology, effective teaching and learning practices and cognitive learning
International Journal of Science Education	Teaching and learning, science
Journal of Chemical Education	Science and technology, education
Journal of Educational Psychology	Education, psychology
Journal of Research in Science Teaching	Scientific education and teaching, science education policy
Journal of Science Education and Technology	Science, technology, education
Learning and Instructions	Learning and development

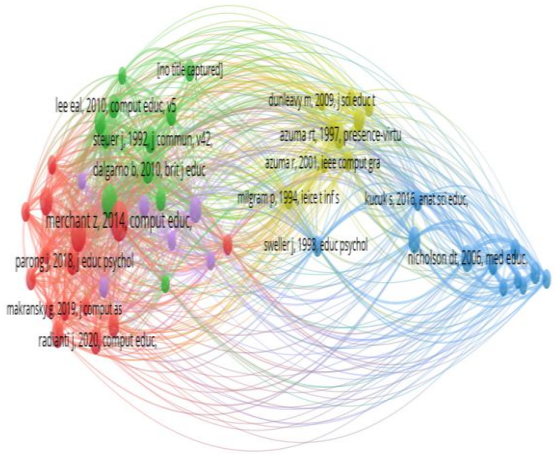
Cluster 3(10 items)	***Teaching and learning***
British Journal of Educational Technology	Teaching and learning, technology
Computers & Education	Technology, teaching and learning
Education and Information Technologies	Education, technology, and development
Educational Technology & Society	Teaching and learning and psychology
Educational Technology Research and Development	Learning and development, technology
Interactive Learning Environments	Information technology, teaching, learning
Journal Of Computer Assisted Learning	Technology based learning
Lecture Notes in Computer Science	Computer science, information technology
Medical Education	Science, education
Management Information Systems Quarterly	Management information systems and information technology

Cluster 4 (3 items)	***Science and Technology***
Academic Medicine Journal	Medical education, innovation and competency training
Anatomical Sciences Education	Science, learning, education
Clinical Anatomy	Science and technology

Source: Compiled by authors

Most Frequently Co-cited Documents

The present study has made use of the co-citation method of bibliometric analysis for documents. A minimum cluster size of three and filters with 15 citations, 1.25 resolution, and have been used. Five clusters were created using the aforementioned filters, and they are described in the figure below.



Source: Compiled by authors

Fig 3: Most frequently co-cited documents

Cluster 1: Virtual Reality

The use of virtual reality in education is the focus of this cluster of fifteen documents. A meta-analysis of the effects of virtual reality training on K–12 and higher education students' learning outcomes has been done in the research (Merchant Z, 2014). They were evaluating the effects of including immersive VR in virtual learning scenarios and figuring out whether multimedia learning concepts applied to immersive VR (Makransky G, 2019). In his 2018 paper, Parong J. stressed the importance of comparing the efficacy of immersive VR and desktop slideshows as instructional media for imparting scientific knowledge. The author also looked into the viability of implementing a generative learning strategy into a VR lesson. The assessment of VR applications in education has primarily focused on their usability rather than their impact on learning outcomes. Immersive VR has primarily been used for research and development purposes, instead of being widely used in conventional classroom training (Makransky G, 2018). The study identified several scenarios in which HMDs are beneficial for skill development, which include cognitive abilities linked to recalling and comprehending sensory and spatial information, motor coordination abilities related to head movements, like visual scanning or inference, and emotive abilities related to controlling emotional reactions in hectic situations (Jensen, L., 2018).

Cluster 2: Virtual Environment

While sensory stimulation, engagement- and immersion-fostering contextual factors are combined with internal tendencies towards participation, presence—which is seen as a frequent consciousness occurrence—is created (Witmer BG, 1998). The authors contend that more research into the precise relationships between the distinctive features of 3-D VLEs and their potential educational benefits should be a condition of investment in and development of 3-D virtual learning environments (VLEs) for educational purposes. B. Dalgarno and M.J.W. Lee (2010). The concepts of "presence" and "telepresence," which define the sensation of being in an environment made either naturally or artificially, are at the foundation of virtual reality. The two technology aspects of vividness and interaction, which are used to create telepresence, further improve the concept.

Vividness and interaction, two technological aspects that are examined, further improve the idea of telepresence. Next, depending on these two criteria, various media types are classified (Steuer J, 1992). First-person experiences, intuitive semantics, dimensionality, transformation, materialisation, self-sufficiency, and immersion are just a few of the VR qualities that are used in a way that complements the educational setting and subject matter (Tassos A. Mikropoulos, 2011). The individual measurement of psychological aspects such presence, motivation, cognitive benefits, control, active learning, and reflective thinking in the learning experience was the key factor influencing learning outcomes in a desktop VR-based learning environment (Lee Eal, 2010).

Cluster 3: Augmented Reality

Immersive learning experiences could now be experienced with the help of virtual reality (VR) and augmented reality (AR) technologies. This study sought to ascertain whether learning about structural anatomy through virtual reality (VR) or augmented reality (AR) applications is as successful as tablet-based (TB) applications and whether these techniques improve student learning, involvement, and outcomes (Moro C, 2017). The multiple-view group had a superior comprehension of the carpal bones compared to the key-view and wiggle group (Garg AX, 2002).

Cognitive load theory has been developed to offer guidelines that can help present information in a way that promotes optimal intellectual performance through learner activities (Sweller J, 1998). Medical students' academic performance and cognitive load were examined by Kucuk S. (2016) in relation to learning neuroanatomy using mobile augmented reality (mAR) technology. To accomplish this, a MagicBook on the subject was produced using mAR technology. With the use of this technology, users can use mobile devices to engage with their environment and incorporate virtual learning items into the actual world.

Cluster 4: Three-dimensional Virtual Reality

The features of augmented reality systems, with a comprehensive examination of the pros and cons of optical and video blending techniques. Two of the main challenges in creating efficient augmented reality systems are registration and sensing errors, so this paper summarizes the current efforts to address these issues (Azuma RT, 1997). Nicholson DT, (2006) concluded that Medical students have acknowledged that 3D-VR technology is a valuable tool for learning human anatomy and is superior to traditional methods. The authors present the various technological, pedagogical, and learning challenges associated with the integration of augmented reality (AR) into education, and explore potential solutions for several of these challenges (Wu HK, 2013). The challenges posed by augmented reality (AR) include usability issues and frequent technical difficulties, as well as other difficulties that were identified (Akcayir M, 2017).

Cluster 5: Immersive Virtual Environment

In the experimental and control groups, there was a discernible difference in how well learners with low spatial ability performed, but there was no statistically significant difference in how well learners with strong spatial ability performed in either group (Lee Eal, 2014). Immersion refers to the subjective feeling of being fully engaged in a realistic and all-encompassing experience. Interactive media has the capability to provide different levels of digital immersion (Dede , 2009). Slater M(1997) proposed the extent of immersion can be objectively measured based on the technology's characteristics and is characterised by several dimensions, such as the ability of the display system to create a comprehensive, encompassing, vivid, and convincing illusion of a virtual environment for the participant. Statistical Power Analysis is an accessible guide to power analysis in research planning, designed to empower applied statisticians with the necessary tools to perform more effective analyses (Cohen J, 1988).

Table 6: Summary of Methodological Approaches and Analytical Techniques

Category	Subcategory	*n*	%
Type of Study	Conceptual/ Review	249	34.68
	Empirical	469	65.32
	TOTAL	718	100
Research Methodology	Quantitative	465	64.7
	Qualitative	190	26.4
	Mixed Methods	63	8.9
	TOTAL	718	100
Data Collection Method	Survey	384	53.5
	Interviews/ Focus Groups	93	12.9
	Experiment	37	5.1
	Mixed Data Collection Methods	57	7.9
	Use-Generated Content/Big Data	63	8.8
	Others	84	11.8
	Total	718	100
Data Analysis Technique	SEM	288	40.1
	PLS-SEM	92	12.8
	Qualitative Content Analysis	139	19.4
	Bivariate	22	3.1
	Multivariate	149	20.7
	Other Statistics	28	3.9
	TOTAL	718	100

Source: Compiled by authors

Table 6 presents data on various aspects of a research study, by categorising the study based on its type, methodology, data collection method, and data analysis technique.

The table shows that 34.68% of the studies are conceptual or review in nature, while 65.32% are empirical studies. Furthermore, the table indicates that the most common research methodology is quantitative, accounting for 64.7% of the studies. Qualitative research accounts for 26.4% of the studies, while mixed methods account for 8.9%. The most common data collection method is survey, accounting for 53.5% of the studies. Interviews/focus groups and user-generated content/big data account for 12.9% and 8.8% of the studies, respectively. Lastly, the most common data analysis technique is SEM, accounting for 40.1% of the

studies. Qualitative content analysis accounts for 19.4% of the studies, while multivariate analysis accounts for 20.7%.

5. Results: A total of 718 studies were included in the analysis. The results indicate that the majority of studies have focused on the use of the metaverse in specific disciplines such as engineering, computer science, and game design. The most common methodologies used were case studies and surveys, and the outcomes of these studies were primarily concerned with student engagement, collaboration, and learning outcomes.

Development in the Literature of Metaverse and Higher Education

The current analysis reveals the rising patterns in metaverse and higher education research during the last decade (2013–2023). These developments have indeed been classified into three categories depending on their prospective application and use in higher education.

Virtual Reality and Augmented Reality

Virtual Reality (VR) and Augmented Reality (AR) are two rapidly developing technologies that have the potential to change the way we live, work, and interact with our surroundings. VR is a virtual environment generated with computer software and gear that allows users to feel immersed in a seemingly real and interactive world. Augmented reality uses a camera, a computer processor, and a display to overlay digital information on real-world objects. The camera records the real-world surroundings, and the computer processor analyses the data before displaying it on the display.

These technologies have their roots in the 1960s and 1970s, when computer scientists and engineers first experimented with the concept of constructing virtual environments (Riva, 2017). Virtual reality and augmented reality are now used in a range of areas, including entertainment, education, healthcare, and military training. VR is being utilised in education to build immersive and interactive learning environments, allowing students to explore and comprehend complex subjects in ways that were previously impossible (Riva, 2017). These are being utilised as a treatment tool in healthcare, assisting patients in overcoming phobias, anxiety, and other mental health disorders (Rizzo & Kim, 2018). These technologies are utilised in the military to train soldiers in realistic and tough conditions, preparing them for the demands of combat (Rizzo, Buckwalter, & Neumann, 2015). Despite its numerous uses, VR and AR are still in their early stages of development and have yet to realise their full potential.

Virtual Environment and Immersive Virtual Environment

A virtual environment is a "computer-generated simulation" that replicates real-life experiences and allows students to engage with the surroundings as well as other people via various devices such as VR headsets, AR, or smartphones. For example, medical students can use virtual environments to practise surgery, while engineering students can use them to simulate real-world construction projects (Bachmann et al., 2019). In entertainment, virtual environments are used to create realistic gaming experiences. Virtual environments have numerous advantages, including cost-effectiveness, safety, and flexibility. Virtual environments provide a cost-effective way to simulate real-world scenarios, reducing the need for physical resources, travel, and equipment. Virtual environments also provide a safe environment to train and experiment without endangering human lives (Bachmann et al., 2019).

Virtual environments provide flexibility by allowing students to participate from anywhere, at any time, and with a variety of devices. Virtual environments also offer personalised experiences, allowing students to tailor their learning to their interests and needs (Jerald, 2015). Virtual worlds offer a plethora of potential for immersive experiences, with applications in a variety of industries.

Immersive virtual environments (IVEs) are computer-generated simulations allowing users to immerse in a virtual world using various technologies such as virtual reality headsets, haptic feedback devices, and motion sensors. IVEs also have limitations when it comes to simulating real-world interactions, such as poor tactile input, which can restrict their effectiveness in some applications, such as surgery simulation (Parsons & Rizzo, 2008).

Three-dimensional Virtual Reality

Three-dimensional virtual reality (3D VR) is a computer-generated simulation of a three-dimensional environment that allows users to engage with and explore a virtual world

through immersive experiences. 3D virtual reality (VR) is used to create highly immersive and interactive gaming experiences that allow players to enter and explore virtual worlds with high degrees of realism and interactivity (Lambooij et al., 2010). "Three-dimensional virtual reality" (3D-VR)-based learning and teaching in medical training has been promoted to increase student learning results. The goal of this study was to compare the efficacy of 3D-VR in human anatomy classes to normal teaching methodologies (Alharbi,2020).

6. Discussions and Findings

This research examines the literature on metaverse in higher education in the last ten years through a bibliometric analysis of 718 articles from 260 reputable journals published from 2003 to January, 2023. The research questions were analysed using citation and co-citation analysis.

The main research questions of this study were investigated using citation analysis. The number of publications touching the metaverse and higher education has gradually increased over the years since its conception, but a significant increase is visible in 2019. There are two stages to the publication pattern.The primary stage (2013-2017) depicts the field's early years, with a small number of publications. However, since 2018, the quantity of publications has steadily increased year on year. With over 160 papers and 4000 citations, the year 2022 has been designated as a watershed moment in this field of study. With 616 citations, the most cited paper in this field is Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant, 2014). Furthermore, the most important authors have been Mayer and Richard E. (in terms of total citations and average citations per document). "Virtual Reality" has the most publications pertaining to the Metaverse and higher education, with a total of 27 so far. Furthermore, the journal "Computers & Education" is the most important in terms of total citations. These results highlight the most important and prominent contributors to the field of Metaverse and higher education, as well as the growing global interest in this field.

An additional co-citation study was performed. Aside from "computers and education," the most frequently referenced publications are anatomical sciences education, journal of science education and technology, and Virtual Reality. According to these results, the top technology journals were also the top contributors in the fields of Metaverse and higher education. Document co-citation analysis revealed five distinct clusters: virtual reality, virtual environment, enhanced reality, three-dimensional virtual reality, and immersive virtual environment. This represents the main areas that have been frequently mentioned. The authors have also identified the most common methodological approaches and analytical techniques used by researchers to conduct studies in this field. The majority of the studies were founded on the literature, followed by empirical studies. The majority of authors depended on quantitative research methods, employing the data analysis technique Structural Equation Modelling (SEM). On the contrary, interviews and focused group discussions emerged as the most popular data gathering methods.

The findings have both theoretical and practical consequences. This study provides some useful insights into the key contributors in the field of metaverse and higher education, as well as the most influential studies, journals, authors, and methods that have fueled this field. Furthermore, the analysis identifies the field's progressive expansion over time and adds to the concept by outlining the main study issues that emerge in the metaverse and higher education. Our research seeks to provide a clear picture of the metaverse's potential to transform higher education. In practise, it would allow academicians and researchers to gain a thorough grasp of the benefits of its application to higher education, such as the creation of creative educational content, enhanced experiential learning, access to global expertise, and improved academic collaborations.

This study would also be useful for researchers in identifying resources (articles, authors, journals, countries, and institutions) that can provide them with useful practical insights into this topic. The study allows researchers to rapidly find the most influential papers, authors, and journals in this field. As a result, one can clearly examine the aforementioned findings to obtain a thorough understanding of the subject.

Journals such as computer and education and Anatomical sciences Education have each published 38 papers in the top 20 list,

demonstrating their keen interest in the field of virtual reality and higher education.

7. Limitations and Recommendations for Future Research

The current study is one of the few that presents the entire literature on metaverse and higher education. Despite the research's precision, importance, and scope, there are some shortcomings that must be addressed. The first shortcoming of the study is the use of a single database (Web of Science) for data gathering and analysis. Studies employing bibliometric techniques frequently employ a single database for analysis in order to avoid the repetition of research papers; however, this strategy may result in the exclusion of some of the most relevant research papers pertaining to Metaverse and higher education (such as Scopus and Google Scholar). As a result, the study's primary limitation is the use of a single database. Furthermore, the research does not address the purpose and significance of citation structure.

This comprehensive analysis of the literature using bibliometric techniques has found a few directions for future researchers in terms of recommendations for future research. Although there is a substantial body of literature on the use of the metaverse in higher education, the findings of this study suggest that more research is required to completely understand the platform's capabilities for improving teaching and learning.More study on the application of the metaverse in other fields, as well as the possibilities of the metaverse for online and blended learning, is suggested by the findings. Furthermore, more research is required to determine the long-term effects of metaverse use on student engagement, cooperation, and learning outcomes.

Finally, a bibliometric analysis of the literature can be carried out using a variety of techniques. This analysis has used only two of the many available methods. Future researchers could use other bibliometric techniques to gain a broader perspective on this subject.

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