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Metaverse Driven Intelligent Information Systems

Emerging Trends and Future Directions

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Contents

The Metaverse: A Multidisciplinary Examination of Opportunities, Challenges, and a Comprehensive Theoretical Framework

Nepoleon Prabakaran, Harold Andrew Patrick, Prema Rajan, and V. P. Sriram

Abstract People today virtually network at various points in their lives. This evolution occurred as a result of the profound introduction of metaverse technologies into various fields such as education and business. In this chapter, the authors tried to look up the merits and demerits of the metaverse. The chapter discussed in detail the various themes and patterns (user adoption, social interaction, educational application, and ethics) provided by the trends of previous metaverse research. This chapter also comprehensively discusses the theoretical frameworks of the existing metaverse studies. Finally, the chapter integrates the variables (dependent, independent, mediating, and moderating) and proposes a new conceptual framework for future research to test the empirical validation.

Keywords Metaverse · Social interaction · Education · Framework

1 Introduction

The lines separating the virtual and real worlds have become more hazy with the emergence of the metaverse and a new technology age. Immersion in a networked virtual environment, the metaverse has the power to fundamentally change social interactions, education, commerce, and many other aspects of human lives [3]. However, the metaverse contains benefits and drawbacks that need to be carefully explored and understood, just as any ground-breaking technology.

The metaverse was originally put out by Neal Stephenson and Ernest Cline and sprang from science fiction. They pictured virtual environments that were always linked to our real identities. Thanks to recent developments in technology including blockchain, virtual reality (VR), artificial intelligence (AI), and augmented reality (AR), the concept has become quite popular. Major IT firms such Microsoft and

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Meta (previously Facebook) have made substantial investments in the creation of metaverse platforms, indicating their conviction in the promise of this cutting-edge technology.

The metaverse will totally change the ways we work, communicate, study, and spend the time. Users may construct, explore, and engage in a shared, persistent virtual world through their digital avatars [15]. With the metaverse, immersion experiences might become feasible, creating new opportunities for cooperation, education, and trade. In the future, the metaverse will have a huge impact on changing reality in fields such as real estate, gaming, and tourism.

The metaverse's excitement actually brings with it a set of problems that require careful attention. In the literature, there is a severe lack of a theoretical framework that is required for the well-established implementation of metaverse systems. The existing frameworks failed to address the complexity and multidimensional aspects of the metaverse with respect to design concepts and societal consequences. To ensure the ethical and sustainable growth of intensive immersive technologies like the metaverse, it requires solid theoretical foundations, which are lacking in the previous literature.

The analysed body of literature suggests that privacy, ethical, and security concerns are necessary for the development of the metaverse [6]. Whenever a human interacts with the metaverse environment, he leaves a digital imprint. We can use these imprints to analyze behavioural patterns and personal information. The misuse of data by organizations or other negative agents raises concerns about our privacy and security. With the increasing capabilities of artificial intelligence, the metaverse has the potential to replicate human experiences [31].

There are many unsolved problems even with the body of research on the metaverse growing. Above all, a complete theoretical framework that unites the several social, ethical, and technological aspects of the metaverse is needed. The literature already in publication, which has looked at specific aspects such social interactions [14, 34], user adoption [35, 36], and educational applications [23, 32], lacks a comprehensive approach.

Secondly, there are few actual research on the long-term psychological and sociological consequences of metaverse adoption. As the metaverse grows, it will need to be closely examined how it affects communities and individuals alike. Investigating potential effects on, among other things, the digital divide, cultural identities, and mental health is part of this. Thirdly, the ethical and legal frameworks of the metaverse are yet developing. Many fields are incorporating the metaverse, making it more valuable and responsible. Therefore, implementation of the metaverse needs strong ethical norms.

2 Thematic Evaluation

2.1 User Adoption and Acceptance of the Metaverse

Implementing the metaverse in any industry requires an understanding of the various factors that influence user acceptance and adoption. Many studies have examined the characteristics of how people accept technology. Researchers have developed the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), which integrates the big five personality traits to understand the social sustainability of metaverse adoption [3]. Several factors, including price value, habit, openness, hedonic drive, neuroticism, consistency, agreeableness, and performance expectations, contribute to this social sustainability. An optimistic view of the utility factor incorporates attachment towards emotion, enjoyment, and ease of use [36]. Furthermore, aspects such as interpersonal interactions, emotional attachment, and perceived user-friendliness benefited people's views and intentions about using the metaverse.

The Unified Theory of Acceptance and Use of Technology (UTAUT) paradigm, applied in engineering education, contained among its elements hedonic motivation, habit, faith in technology, and cybersecurity [35]. The behavioral intention to use metaverse technology for learning was significantly influenced by hedonic reward, social influence, performance expectation, and cybersecurity; cybersecurity had the greatest effect [35, 36].

2.2 Social Interactions and User Experiences in the Metaverse

Offering multimodal, immersive virtual worlds, the metaverse has the power to fundamentally change user experiences and social interactions. Many scholarly research have examined how the metaverse might enhance social interactions and user experiences over conventional two-dimensional internet platforms. The purpose of the study [15] was to determine whether users may gain more in terms of emotional reactions and communication clarity from real-time, multimodal social interactions in the metaverse—made possible by virtual reality headsets—than from 2D online platforms like Zoom meetings.

The study [14] investigated over time in the metaverse how various avatar identities and virtual environments impacted social presence, enjoyment, and nonverbal synchrony—a term denoting parallels in moment-to-moment nonverbal behaviors. As opposed to uniform avatars, self-avatars improved self-presence and realism but reduced delight, although participant-like avatars improved nonverbal synchrony.

Emphasizing avatar fashion style, the study [34] looked at how competition and self-expression affordances impact metaverse enjoyment and involvement intentions. Conclusions of the study revealed that users' views of enjoyment were benefited by

competitiveness and self-expression, which in turn influenced their inclinations to engage in the activity.

The study [16] examined how user incentives for using the metaverse—desire for benefits, extended social contacts, and virtual experiences—affected flow experience. Finding advantages, staying in social situations for a while, having fun, and being aware of transfers all improved metaverse utilization.

2.3 Metaverse and Education

The metaverse has promising prospects to improve learning, especially in the domains of social interaction and immersive learning settings. A great deal of study has looked at how metaverse platforms might be used in education. Using "Gather.town," a video conferencing software that lets users create avatars, researchers reported enhancing social connections in chemistry laboratory courses in an online learning environment during the COVID-19 pandemic [23]. Based on their empirical results, students agreed that the atmosphere of a particular platform improved student interaction in the virtual learning environment.

Concurrently, study [25] examined how art history students used the metaverse platform Gather. Town and felt social presence, interaction, and involvement. Gather Town's applicability and legitimacy as a teaching tool in art history were assessed by the researchers' using criteria like accessibility, social presence, participation ease, interest, and study immersion.

The configuration of the education to wider reach was accounted by the 'Learningverse' platform paved the way by promoting social, cognitive, and pedagogical presence [32]. This particular platform makes the user to assemble the solar system in a immersive environment. This one particular feature of the platform grabbed the optimistic impressions of multiple users [32].

2.4 Ethical, Privacy and Security Concerns in the Metaverse

Facebook's business model analysis has examined the potential discrepancy between the depicted and real metaverse states [18]. Researchers have conducted numerous studies on the ethical implications of complex rebranding initiatives, examining their effects on both business and society.

The platformization of corporations, the COVID-19 pandemic and its effects on corporate governance, privacy, security, and data management, as well as the dangers and implications of the metaverse, are all important concerns [5, 6]. The authors' research has identified differences and disputes regarding the platformization of urban cultures, which the metaverse mediates [4, 5]. This has led to a concern that public ideals are deteriorating.

Researchers investigated the use of avatars to facilitate human-like interactions and determine whether users were interested in using digital healthcare services in the metaverse. The researchers looked into how emotional sensitivity and perceived anthropomorphism affected how these intentions developed. Their investigation into the potential hazards associated with the algorithmic mediation that forms the foundation of the metaverse raises moral concerns about the application of these technologies, particularly in sensitive domains such as healthcare [31].

2.5 Business Applications and Marketing in the Metaverse

Consumers have a desire to purchase a fashionable digital product because they perceive its value through their continuous involvement in two important dimensions of metaverse ecosystems (telepresence and social interaction) [26].

During a live performance by influencers on Instagram, a social media user exhibits peculiar behaviours and experiences [4]. The researchers looked at the role that content participation plays as a moderator in the connection between telepresence and evaluations of both instrumental and experiential value. In comparing live-stream buying experiences on two well-known platforms—Instagram and the metaverse—this study is novel.

The study looked at the wide-ranging impacts of the metaverse on marketing, entertainment, healthcare, and society at large [12]. Academics are looking at how broad metaverse adoption may affect a number of areas, including social interactions, privacy, trust, bias, disinformation, legal applications, and psychological issues including addiction. This comprehensive method gives perceptive details on the potential advantages and difficulties that businesses and marketers could encounter in the metaverse.

2.6 Societal Implications of the Metaverse

In a study [29], Japanese attempts to link ordinary social interactions to American metaverse platforms are critically analyzed. By means of the "otaku" (exclusive) cultural politics idea, this study draws attention to issues about the degradation of actual social spaces and the commercialization of social life on corporate digital platforms [29].

Given that teenagers are probably regular metaverse users, the negative effects of social media addiction and online gaming on their mental health [20]. Their results provide empirical support to the idea that young people's psychological health may suffer from metaverse immersion [20]. the challenges and opportunities of creating a circular economy in the metaverse by means of virtual good recycling and reuse [11]. Important concerns regarding waste management, resource sustainability, and the consequences of an increasingly digital economy on the environment are brought up

by this work. Research looked at the ways that metaverse tourism impacts the visitor experience, the opportunities and challenges facing the industry, and the impact of the phenomena on society and the environment [9]. Although the paper [9] highlights how metaverse technology may enhance immersive and personalized travel experiences, it also acknowledges the need of considering how it may eventually impact local economies, people, and the environment.

3 Existing Theoretical Foundations and Frameworks for the Metaverse

Many of the papers in the provided literature address the subject of conceptual frameworks and theoretical foundations for comprehending the metaverse. With these endeavors, theoretical frameworks that can be used to study the fundamental principles, elements, and consequences of the metaverse are to be provided. A study was done [2] to map the just developed metaverse products and services and look at how they might help with sustainability goals in the social, economic, and environmental domains. The immersive depiction of smart cities paved the way for understanding the conceptual framework that assesses factors influencing the urban sustainability of the metaverse. Data-driven systems play a crucial role in the operation of the metaverse, facilitating interaction between virtual cities [7]. Algorithmization, platformization, datafication, and hyperconnectivity contribute to some of the components of this data-driven system. With the application of artificial intelligence, neurotechnology, extended reality (XR), and nanobiotechnology, a speculative paradigm envisioned the metaverse as a platform urbanism simulation [5]. This paradigm looks into the connections and impacts of various combining technologies in the metaverse. An architecture was developed to differentiate the metaverse from previous virtual worlds according to user experience [27]. Looking at sites like Second Life, they were able to pinpoint features of the metaverse that emphasize both its unique features and potential disadvantages (Fig. 1).

The figure shows the multiple frameworks—data-driven processes, urban sustainability, technology convergence, and user experience—that have been put forward by different research to comprehend the metaverse from different angles. Through an analysis of novel features, technology integration, sustainability implications, and fundamental digital and computational processes, these frameworks seek to offer a thorough grasp of the methods, components, and results of the metaverse. The image emphasizes the significant contributions that every study contributed to the development of theoretical frameworks and foundations for understanding the intricacy of the metaverse.

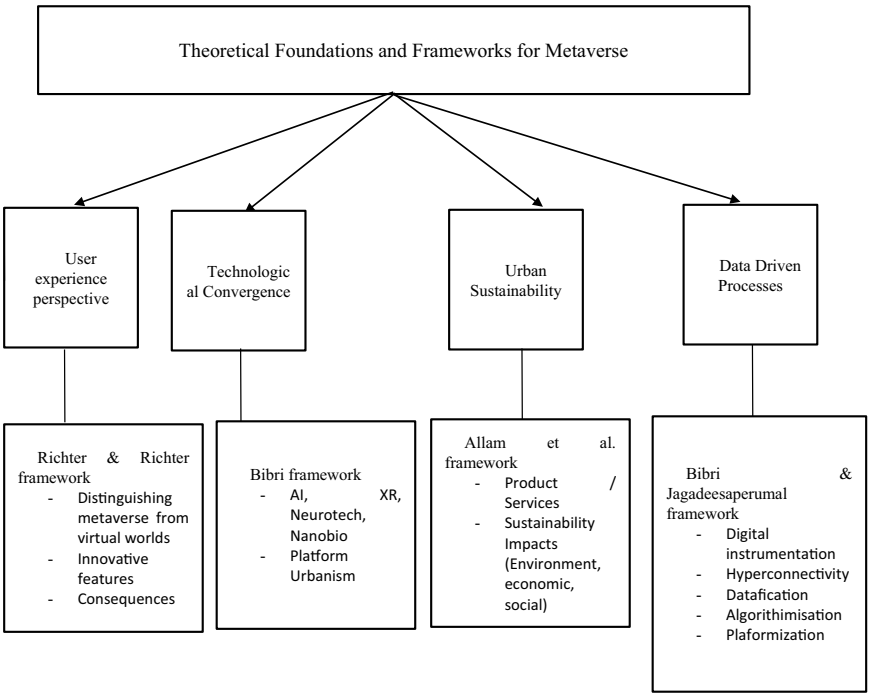

Fig. 1 Categorizing the existing theoretical frameworks

4 Opportunities in the Era of Metaverse

Users interact avatar-based in the immersive virtual world known as the Metaverse [2]. The Metaverse can revolutionize the way services are offered and cities are planned in order to improve urban accountability, efficiency, and high-quality performance [2]. The metaverse as an array of digital platforms and ecosystems, wherein each ecosystem is a self-contained cosmos possessing unique materials, complementors, and capabilities [30]. Requirements for complementors, consumers, platform owners, and orchestrators change as a result of the development of immersive ecosystems that constitutes metaverse [22]. The metaverse offers significant opportunities for digital innovations that extend beyond conventional social media and computer games, in addition to establishing new infrastructures for add-on innovations in various sectors of the digital economy [19]. The creation of online markets for used things is one possibility. An additional opportunity arises from the simulation of the environmental impact of various products and production methods using virtual reality [11].

5 Challenges

Notwithstanding the many advantages and bright futures of neurotechnology and nanobiotechnology, disputes and controversies are brought up by their possibility to damage operators over the unregulated black box of algorithmic mediation that forms the foundation of the Metaverse [5, 8]. But concerns about the Metaverse's impact on the caliber of human social relationships continue to exist on ethical, human, social, and cultural levels [2, 13]. This raises several questions about the algorithmic processing and systemic gathering of users' biometric, brain, and personal data; these questions have significant societal and, perhaps most importantly, ethical ramifications [5, 10]. By respecting and maintaining ethical standards, the results guide the Metaverse to promote human flourishing and wellbeing [1, 5]. As there is still a digital gap, one of the issues is making sure that everyone has access to it [11, 12]. Securing appropriate recycling or reuse practices for virtual products and monitoring their lifecycle presents a formidable task. To establish a full circular economy system, it is imperative to coordinate both virtual and physical endeavors [21]. The Metaverse has a significant and transformative impact on the ways in which reality is reconstructed in a society that is becoming increasingly reliant on platforms [2, 17]. Moreover, these tools let academics, professionals, and policymakers assess their benefits and drawbacks, focusing especially on the inevitable ones [22, 33].

6 Comprehensive Framework Proposal

The metaverse, an immersive and interconnected virtual environment, promises to revolutionize various aspects of our lives, from social interactions to education, business, and beyond. However, as a transformative technology, it presents both opportunities and challenges that demand careful examination and understanding. To address this need, a comprehensive theoretical framework has been developed to provide a holistic perspective on the metaverse, integrating insights from multiple disciplines including computer science, psychology, sociology, ethics, and law.

6.1 Independent Variables

Three primary independent factors are assumed by the current paradigm to affect the acceptance, experiences, and outcomes associated with metaverse technology. Above all, the development of metaverse platforms is mostly influenced by technology, which includes blockchain, augmented reality, virtual reality, and artificial intelligence [29, 33]. Second, user attributes like personality features, motivations, and technical readiness affect people's attitudes, perceptions, and intentions toward adopting and using metaverse technologies [8, 13, 19]. Moreover, features of

metaverse platforms such affordances, virtual environs, and avatars influence user experiences, interactions, and results inside the metaverse environment [1, 26].

6.2 Dependent Variables

The proposed framework encompasses several dependent variables influenced by the independent variables and mediated or moderated by other factors. User adoption and acceptance of the metaverse are contingent upon technological factors, user characteristics, perceived usefulness and ease of use, enjoyment, social presence, and trust and privacy concerns [15, 20, 28]. User experiences and social interactions within the metaverse are shaped by platform design features, social presence, interaction quality, and immersion [13, 14, 16]. Educational outcomes in metaverse-based learning environments are dependent on platform affordances for interactive and immersive learning, social presence, and user experiences [10, 11]. Business and marketing performance in the metaverse is influenced by platform capabilities, user experiences, perceived value, and intentions [24, 27] Finally, societal impacts, encompassing cultural, psychological, environmental, and economic effects, emanate from the adoption, use cases, and widespread implementation of metaverse technologies across various domains [9, 20, 29].

6.3 Mediating Variables

Several mediating variables are included into the framework to clarify the social and psychological processes by which the independent variables affect the dependent variables. User adoption and experiences are mediated by perceived usefulness and simplicity of use of metaverse platforms [32, 35]. Effects of design elements on user experiences, interactions, and educational or commercial consequences are moderated by enjoyment and immersion in metaverse encounters [14, 16, 34]. Design elements influence user experiences, social interactions, and educational results in the metaverse through mediation of social presence and interaction quality [14, 15, 23]. Technology aspects, user traits, adoption and acceptance are mediated by trust and privacy issues associated with metaverse platforms [5, 31, 35].

6.4 Moderating Variables

In order to influence the overall outcomes and implications of metaverse technology, the proposed paradigm incorporates a variety of moderating variables that can either amplify or diminish the correlations between the independent and dependent variables. Age, gender, and cultural background will alter a user's experience because

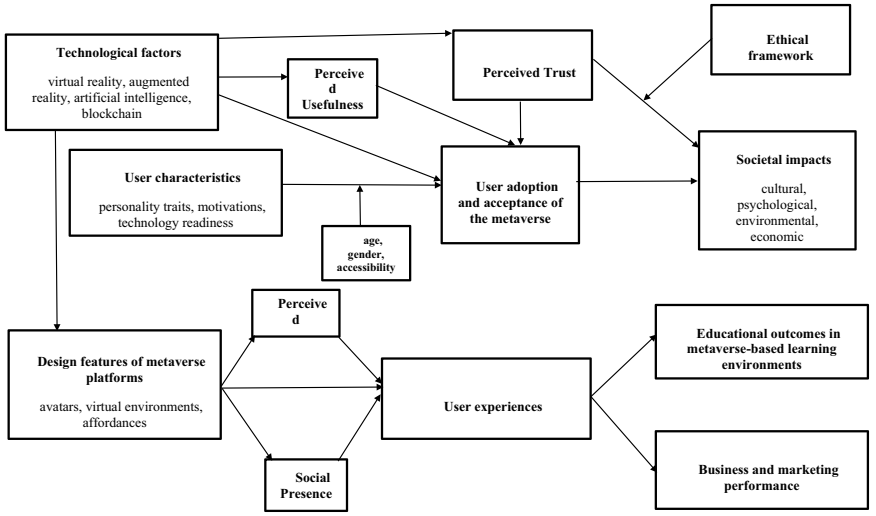

Fig. 2 The proposed conceptual framework

each factor varies depending on the user's characteristics and design elements [3]. The ethical frameworks will moderate the relationship between metaverse technologies and their influence on society [17, 31]. Infrastructure and accessibility influence the adoption, diffusion, and equitable access of metaverse technologies in various contexts [11]. Industry-specific factors have a moderate effect on the implications of the metaverse across different sectors and business models [9, 12] (Fig. 2).

7 Conclusion

A fast-developing technological area, the metaverse presents both special opportunities and difficulties. This theoretical framework integrates concepts from several disciplines to try to give a thorough grasp of the metaverse and its intricate ramifications. It emphasizes the interactions that affect adoption, experiences, and results between user characteristics, technological elements, and design elements. The paradigm admits that in order to establish the relationships between independent and dependent variables, mediating factors including pleasure, social presence, perceived utility, and trust difficulties are necessary. It further admits that the general advantages of metaverse technology can be impacted by human variances, ethical and regulatory frameworks, infrastructure accessibility, and industry-specific factors. User acceptance, social contacts, educational outcomes, business performance, and societal effects are just a few of the industries that the metaverse impacts. Multidisciplinary approaches are required to ethical, privacy, and security issues since they have a big influence on mental health, environmental sustainability, and cultural identities. The

structure offers a foundation for next metaverse-related empirical study, theoretical development, and policy creation. A responsible development that enhances human well-being while preserving social norms, individual privacy, and environmental integrity could be made possible by an understanding of the complexity and possible hazards of the metaverse.

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Immersive Marketing and Advertising Information Systems

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Abstract This article explores the evolution and impact of Immersive Marketing and Advertising Information Systems (IM&AIS) on the marketing landscape. IM&AIS, leveraging technologies like Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI), create immersive experiences that transcend traditional advertising by fostering emotional connections and deeper engagement with brands and products. The article examines the importance of IM&AIS in building brand loyalty, enhancing customer understanding, and delivering personalized advertising campaigns. It analyzes the components of IM&AIS, including VR, AR, and AI integration, and discusses their diverse applications across industries. Despite the potential of IM&AIS, challenges such as privacy concerns, integration with traditional marketing strategies, and the emergence of virtual influencers are discussed. The article highlights the need for robust data security measures, clear regulations, and creative integration with existing marketing approaches. The conclusion underscores the transformative potential of IM&AIS in shaping the future of marketing. As technology continues to advance, IM&AIS will revolutionize brand-consumer interactions, creating more engaging and impactful experiences that drive brand loyalty and customer satisfaction.

1 Introduction

The evolution of marketing and advertising has undergone significant changes over the past two decades. Marketing and advertising have moved from static imagery and messaging to an immersive experience, laden with user interaction and countless intangible elements. This "immersive experience" has been a broad term to encompass the shift from traditional media messaging and advertising to an overall experience with a brand or product. Interactive video games, online advergaming, virtual reality simulators, and the integration of digital media in everyday experiences

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have all become facets of immersive marketing and advertising. With this movement, marketing is increasingly being viewed as an expendable feature of a product or brand, rather than as a separate entity or production. Immersive marketing will define a product or brand through experiences that will create an emotional attachment and association. This statement outlines one of the most significant differences between traditional advertising and immersive advertising: the attachment of emotion and experiences compared to the conveyance of a message. As the market continues to move towards the marketing of experiences, Immersive Advertising and Information Systems will be used in tandem, becoming indispensable features on marketing initiatives [1].

1.1 Definition of Immersive Marketing and Advertising Information Systems

Immersive marketing is a concept that is not entirely new, but has only recently garnered attention and interest. Immersion can be defined as the feeling of being surrounded by a certain environment. Immersive marketing aims to create a simulated environment through visual, aural, and physical stimuli embedded in a unique, multisensory (and usually interactive) experience in order to create a relationship between the consumer and the product. Immersive marketing strategies can be utilized within the marketing firm, as well as in cooperation with other firms. The degree of participation can vary from using a 3-D environment to package and promote a product, to creating an entire event, such as a snowboarding competition, to associate the event with the product. Beer companies are often cited as using immersion strategies very well. Red Dog and Miller Lite both use various event promotions to associate their product with fun, excitement, and the thrill of victory. An emerging strategy in the field of immersion is the creation of branded entertainment, which involves the development of entertaining content, such as video games or short films, funded entirely by a brand to subtly associate the content with the brand. Immersive marketing is in essence, a long term brand strategy and it is more focused on emotion, experience and interactivity consumer and involving more to marketing. This strategy is taken in contrary to the traditional advertising and marketing strategies in the past. There are three levels of immersiveness: low, mid, and high. High immersive marketing is the most effective strategy and is what most of the market is aiming for today. High immersive experiences have high interactivity and a sense of presence. The more immersive the experience is, the higher the time and the commitment given by the individual towards the event or product. Immersive marketing and advertising information systems are put into place to help strategize and prolong the immersive experience and maximize on the commitment and spending by the consumer [2].

1.2 Importance of Immersive Marketing and Advertising Information Systems

With products becoming more complex and a lot of media clutter in today's advertising and promotion, immersive marketing believes that when consumers interact directly with a product experience, they are more likely to form a purchasing intention due to ease of understanding and product satisfaction. Product simulation in immersive marketing also enables consumers to test a real product without the risk of damaging it or receiving injury during product usage [3].

Immersive marketing also has its own unique selling points compared to traditional advertising and promotion. It seeks to create a long-lasting consumer experience and memory towards the product being marketed. The high level of consumer interaction in immersive marketing also leads to better understanding and attention from consumers towards the marketed product. This can result in positive brand recall and attitude. Ultimately, these objectives efficiently improve purchase intention among consumers [4].

Highly interactive, involving, innovative, experiential, and consisting of multiple two-way communications between consumers and marketers, immersive marketing provides consumers with the ability to experience a product before buying it. This concept can also be applied using traditional media, where consumers' senses are surrounded by auditory or visual elements. Nowadays, technology has opened up a new and vast emerging way of immersive marketing using the internet. This approach blends a mix of virtual reality, augmented reality, and 3D animation to market and advertise a product [5].

1.3 Evolution of Immersive Marketing and Advertising Information Systems

The main question is how did we get from traditional advertising to IMC? The evolution of advertising has taken us from ancient Egypt, where signboards were used to promote tradesmen, through to the rapid expansion of mass production and the innovation of radio advertising in the 1920s. It was during the war years that the development of persuasion, strategic bombing, and psychological warfare was utilized to propel the growth of advertising to the point where companies started to employ in-house advertising. Advertising agencies subsequently played a crucial role in the evolution of advertising; in 1842 Volney B. Palmer established the first American advertising agency in Philadelphia, and thereafter advertising agencies continued to develop through the innovative use of specialist sell and brand advertising [6].

Since then advertising experienced continuous technological advancement and a parallel development of advertising theory, culminating in today's omnipresent digital media and IMC practice. The internet and ICT are undoubtedly the most significant factors in the evolution of advertising from traditional to IMC. Key aspects

of the direct relevance of internet and ICT to IMC are the capabilities of customization and one-to-one communication: and of all forms of digital advertising, it is the immersive type which is most effective in engaging the consumer in this interactive environment [7].

2 Components of Immersive Marketing and Advertising Information Systems

A wide variety of marketing and advertising information systems can be employed to enhance customer immersion. From the World Wide Web to Virtual Reality Modelling Language (VRML) technologies, the range of available systems is considerable. However, this study will focus on the most cutting-edge technology in immersive marketing and advertising systems, referred to as Immersive Marketing and Advertising Information Systems (IMAIS). Bearing in mind the industry implications this technology may have, it is important to realize the potential this technology has for changing the face of marketing and advertising. This technology is designed to improve customer satisfaction, memory retention, and overall learning experience. This is particularly relevant to advertising because customers who enjoy an advert are more likely to remember the product and feel a positive attitude towards it. IMAIS are designed to involve the customer in a memorable experience that will transfer into a purchase attitude and then a purchase behavior at a later date. This technology has obvious implications for the gaming and education industry and may extend to all multimedia in the near future. The basic conjecture is that higher immersion systems will foster a better experience for the user, with the general purpose of these systems to allow simulated activity, experience, and education to seem more realistic to the user. IMAIS are systems that change the usual way advertisements have been presented and therefore have implications for the future of advertising. This technology seems close to science fiction. However, considering the way technology is advancing, even in the last 5 years, it seems to be in the foreseeable future. Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) are the cornerstones of these systems and are explained separately below. These systems are currently in their infancy and can only be found in bits and pieces around the web, software, and gaming industries. VR and AI have been simulated in educational environments and some training simulators. [8]

2.1 Virtual Reality (VR) Technology

There are two main types of VR systems, fully-immersive and semi-immersive. A fully-immersive VR system is designed to place users within a simulated environment, which responds and changes in real-time as the user interacts. Because of

the degree of interaction, users must be able to move around in a fully immersive environment. A fully immersive system usually consists of a head-mounted display (HMD) with 3D goggles and stereo earphones, a data-glove and/or bodysuit with position trackers. The Polhemus motion tracker is a common device used to track the position and orientation of a user in a fully immersive system. The user input gathered by these devices is used to control the user's 'avatar' within the simulated environment. The avatar is the graphical representation of the user. Semi-immersive VR systems are less complex, and by nature restrict the user to a limited area. These systems are typically used in a VR lab, with projects ranging from supporting design and engineering tasks, to using VR for 3D tele-conferencing. An example of a semi-immersive system project is the Virtual Reality Robotic Assembly cell, programmed to aid the training of mechanical engineering students for real-world scenarios. This project was carried out using the OpenGL utility toolkit and is being further developed to include interaction with the aid of a haptic device [9].

2.2 Augmented Reality (AR) Technology

Augmented reality combines the client's present reality with a virtual one. This is achieved through recognition of a symbol, usually a black and white symbol, which then triggers the AR feature. This is currently being utilized for advertising and marketing purposes through the sale of AR postcards and recognition of product logos. Users can hold the physical product in their hand or touch the real-world postcard while their monitor displays a 3D computer-generated model that can be manipulated in real time. A user might rotate the card in reality, and the virtual 3D model will also rotate in real time, creating the illusion that they are moving the real product [10].

An example of this is the AR Magic Mirror being developed by IKEA, in which a user points a webcam at a place where they would like to put a piece of IKEA furniture, and in their monitor's display, the piece of furniture will appear as if it were really there. IKEA claims that this will help to reduce the rate of dissatisfaction in their customers, as they will have a better understanding of what they want to buy and whether it is suitable for its intended place. AR tools such as this mirror have an advantage over real-life products and models in that they are cost and space effective [11].

2.3 Artificial Intelligence (AI) Integration

AI integration is pivotal to enabling the immersive technologies of VR and AR to deliver value to the consumer in the marketing context. AI has the potential to produce extremely rich simulations by layering on learned details about how the real world works and how humans behave. The more an AI system knows about the world,

the better it can tailor a virtual world to match the customer's mental model. For example, AI can learn patterns of consumer behavior and deliver a virtual simulation precisely tailored to what the consumer is likely to respond to. This simulation could, in theory, be a virtual store showing the consumer products that it knows the consumer is interested in viewing. AI can also automate the process of sorting through massive amounts of consumer data collected from VR and AR simulations to better understand behaviors and deliver products. For example, AI can automate the process of categorizing gaze data collected from a VR simulation of a store to make inferences about what types of layout are most effective for which types of consumers. This can greatly reduce the costs of understanding and improving marketing strategies through immersion [12, 13].

Artificial intelligence (AI) is the intelligence of machines and the branch of computer science that aims to create it. AI has substantial relevance to the study and practice of marketing (Sheth 2016). AI has developed a notable capability to understand and replicate certain human behaviors. In recent years, companies are using AI to map consumer personas and using this technology to predict behavior, allowing companies to tailor specific marketing messages for specific consumer targets. Furthermore, AI is being used to automate and personalize marketing and the customer experience, providing the right information to the right person at the right time on the right platform—without human intervention. More specifically, AI is being used to match appropriate colors, context, layout, format, and tone of voice to build advertisement content by analyzing consumer behavior and learning from previous patterns. AI has enormous potential to create and add value for customers through improved marketing and advertising strategies [14].

3 Applications of Immersive Marketing and Advertising Information Systems

Personalized advertising campaigns A suite of software tools has been developed to provide real-time 3D graphics rendering, integrating market-leading capabilities for the creation, management, and targeted delivery of immersive 3D ads, and for performance-based ad analytics. These tools actively enhance a content delivery strategy, enabling the specific delivery of a brand or product-specific ad to be well-matched to a consumer or a situation. This can be achieved through a content recommendation engine that analyzes the choices of a customer and uses this data to predict future choices. Having an ad that changes in real time based on the specific user increases the effectiveness of that ad. It is far easier to capture a person's attention if an ad is showing something relevant to that person. But, the most effective campaign will tailor an ad to attract a broader range of customers, across various demographics. In order to do this, an ad analytics tool can be used to track the effectiveness of an ad and assess customer behavior in response to said ad. This analytics data can be

used to understand what works and doesn't work, and will provide insight into what changes need to be made to an ad to make it more effective [15].

Enhancing customer engagement The essential driver behind immersive advertising is to engage clients. Using conventional media, a customer is exposed to multiple streams of messages and it's not clear whether the message has reached them. This is because most traditional media is passive in nature. For instance, in the print medium, although a reader may be looking through a magazine, the ad may be simply skipped. However, the use of techniques such as 3D interactive games or virtual reality building tours ensure that the consumer is actively involved with the product, and thus the ad, ensuring that the message has been received. With immersive media, results can be easily measured. This is possible because of the simulation's capability of tracking all decisions and actions made by a client. This information is very valuable as it can be used to determine a demographic profile of a potential consumer. Also, because the consumer is more involved with the product, brand loyalty can be fostered. For example, Esquire magazine generated a 29% increase in page views and a 43% increase in ad recall using an immersive 3D ad campaign (Wired 2008) [16].

3.1 Enhancing Customer Engagement

The applications of IM&AIS are extremely diverse. The increasing rate of digitalisation and the rapid growth of the internet, it is timely that we consider the potential impact of IM&AIS given the ever-changing nature of contemporary marketplaces. While the web continues to evolve and grow, new opportunities to engage consumers in richer forms of dialogue that involve two-way, interactive communication are emerging. IM&AIS will provide marketers with more sophisticated tools for engaging their customers in dialogue and for developing deeper and more meaningful relationships with their customers. This is precisely what IM&AIS are designed to facilitate for its very philosophy is to use the technology to create vivid, memorable, and emotional connections between consumers and brands regarding product. So, for example, web-enabled virtual communities where IM&AIS create a digital environment that closely resembles the real world, will create a social arena in which consumers can interact with brands around the world, anytime and anywhere. In this case, life virtual environments might even have music playing, that is a good cue for a music event organizer to invite consumers to interactive chat within the music portal, where the organizer can get feedback while giving away freebies [29].

A key feature of these opportunities is that IM&AIS are designed to be as consumer-centric as possible. Immersive media allow consumers to control their environments and the sequence in which they experience an offering. They are capable of making choices that will determine what happens next. This is something that will appeal to those who are adept in the avoidance of traditional advertising mediums and it's especially effective in getting and holding the attention of potential customers. A study conducted by Chrysler whereby they compared consumers who

tried a virtual experience with one of their vehicles and non-virtual experience found out that it increased the likelihood of consideration by 60% and the amount of time spent configuring the car were increased tenfold. Self-configuration is another feature of IM&AIS that will increase customer engagement; intelligent product agents with 3D representation will assist customers in building a custom-made product with visual aids. Such endeavors will increase conversion rates from configuration to actual purchase [17].

3.2 Personalized Advertising Campaigns

Remark gives impression to be doing an effective personal selling evaluation. Using data mining techniques RSA can create scenarios of how their current and potential customers behave when purchasing insurance products. By using these scenarios RSA is able to simulate the behavior of the customer and understand root causes of why the customers acted in that way. This is key to understanding how to influence customers to behave in more profitable ways [18].

Personalization designates what sort of effort the individual prospect is meant to receive. It is expected to convene the customer's needs and expectations and is anticipated to work towards a specific response. A very personalized approach conveys to the customer that the marketing communications are composed expressly for him. This feature is the key why personalization has been costumed the mass customization, because it simulates a one to one conversation between a seller and buyer on a mass scale (M. J. Etzel, B. J. Walker, 2007, p. 489) [19].

3.3 Interactive Product Demonstrations

Interactive product demonstrations using immersive advertisements represent a new form of advertising communication in which the consumer becomes actively involved in the ad, in the process generating a product or brand experience. Demonstrations have been defined as a form of marketing communication in which the marketer provides information allowing the consumer to try, evaluate, or test the product. Traditional demonstrations can take many forms, e.g. the food demonstration in a retail store, the travelling road show demonstration, the infomercial, or the free sample. These types of demonstrations generally involve manipulation of the product in real-time, often with the demonstration providing the marketer with an opportunity to close a sale. The transfer of this form of demonstration to the computer and internet environment is already occurring. Emerging from this trend are technology and computer-based companies that advocate the use of traditional demonstration marketing strategies and tactics within the online environment. This is seen, for instance, in the offering of free trial software and the increased use of television shopping channels using companion websites to sell products. While these

marketing strategies are based around real-time manipulation of the product being demonstrated, in a broader sense they represent a migration of the demonstration-style marketing communication away from bricks and mortar and into the online environment. Finally, the most recent evolution of online demonstration marketing is the adoption of a more interactive form of advertisement in which the demonstration represents the entire ad and the consumer becomes actively involved in generating the product or brand experience [20].

4 Challenges and Future Trends

However, greater data collection directly means greater invasion of privacy. In a case where a consumer's purchasing behavior can be tracked through an entire virtual environment, the potential available data to be collected is profound. This could mean a log of every movement and decision the consumer made in an attempt to influence his product purchase. This data will be very useful for the marketer but quite intrusive to the consumer and research ethics boards. This directly conflicts with the natural progression of marketing research [21].

As marketing research and methods have improved significantly over the years due to better data collection and analytical methods, the demand for more ways to promote a product has also increased. This has led to a battle for advertising space within various forms of media. For example, the cost for a commercial space on TV has increased significantly due to an increased number of channels available, and other forms of advertising such as pop-ups on the internet and product placements in movies and video games have further increased the costs and competition. This has led to some innovative tactics for creating a more personable connection between product and consumer as an attempt to increase brand loyalty and product sales. This is the ideal environment for immersive marketing and advertising [22].

With faster internet, larger bandwidths at a cheaper cost, and vast improvements in computer graphic techniques, there have been great advancements in immersive technologies, including immersive marketing and advertising. Although all these advancements give great opportunities to this relatively new industry, there are also major concerns from the public and technical standpoints that need to be addressed. Some of these concerns include privacy issues from the vast amounts of personal data collection now possible through these new technologies, integration with traditional marketing methods, and the potential of virtual influencers to replace the real thing [23].

4.1 Privacy and Data Security Concerns

When the full implications of data collection and profiling in cyberspace reach public consciousness and government regulatory efforts, there is likely to be an intense

backlash over the loss of privacy. Concern over privacy will always be an issue in marketing, especially in database marketing. There is thus a need for more explicit and enforced privacy principles for the internet. The direct marketing industry's attempts at self-regulation have produced limited success in part because of a stance that has sought to maximize industry freedom to collect and use information about consumers while minimizing regulatory constraints. New legislation has been or is being enacted in various countries to ensure that there are clear boundaries for what can legally be collected and with whom it can be shared and to give consumers greater knowledge and control over information kept about them. This will make the traditional practice of buying lists of contact details and data appending activity less viable with time. High-quality customer data will increasingly need to be proprietary. These legal and market-driven developments are to some extent at odds with the potential of immersive marketing insofar as the more elaborate data gathering tools embedded in immersive environments have conflicting implications with desires for consumer privacy. While virtual reality and gaming technology have been rapidly evolving and progressing, there are already challenges in adapting the existing laws and self-regulatory industry codes of practice to emerging forms of immersive media. The principles underlying the regulation may need to be different for media in which ads are delivered through virtual characters and placed within simulations of public places. The existing privacy legislation at the time of this writing may become outdated before immersive marketing really takes off. Measures to maintain privacy in immersive environments may need to include requirements for data minimization and constraints to prevent tracking of consumer behaviors across multiple simulations over long periods of time. For the individual company looking to use immersive marketing, there may be a need to future-proof investments by ensuring that data collection tools and consumer profiling capabilities are sufficiently flexible to adapt to changing regulatory requirements. This is not to say that immersive technology cannot be used in advertising, and there is potential for a win–win situation where a more entertaining and involving form of advertising can be matched with games and simulations designed specifically as branded content and an alternative to general-purpose entertainment simulations. However, striking the right balance between privacy protection and consumer benefits from immersive media will be a significant challenge [24].

4.2 Integration with Traditional Marketing Strategies

It is believed that the current competitive environment for companies has led to a renaissance in the perspectives and disciplines of marketing by way of the changes in consumer preferences and customer desires. This often leads to an often-overlooked point that companies may have entered the era of marketing myopia. Rather than defining and addressing consumer needs and wants, companies are defining their goals through broad product-market terms; building too many goods that nobody wanted in the first place. Thus, global companies today face the challenge of accessing

the benefits of emerging technology and media in a quest to integrate or reinvent diverse marketing strategies to remain close to the consumer. The leap in technology has created a worldwide web of market research in the form of industry forums, web 2.0 sites, and a whole range of 'Software as a Service' (SaaS) options from data mining to online surveys. These methods, although valuable, are still disparate from a wide array of traditional marketing strategies which can still be cost-effective and efficient. There are new and innovative tools to integrate traditional marketing activities into a more comprehensive marketing process. Take, for instance, immersive virtual reality simulations for brand or product trials. Often these simulations can be a module to a game or a product feature on its own. An example would be Audi's Virtual Reality Car Configurator, where consumers can experience a 3D sports car environment and build the car to their preferences. This tool is not only an interesting product feature, it is also a simulative and more engaging alternative to the traditional showroom product trial, providing valuable insights and consumer feedback. This is in line with the consumer engagement marketing mix, which shifts the promotion of a brand through advertising to the active involvement of the brand with its consumers. Audi's virtual reality tool can be supported with a public relations event or viral advertising campaign and cell phone text-in competitions, linking consumers to online sweepstakes and more notably, offline activities with a chance to experience the virtual simulator. Audi can track consumer feedback and experience various consumer perceptions of the brand in all these activities [25, 26].

4.3 Potential of Virtual Influencers in Immersive Marketing

Research and academic opinion indicate that the future has strong potential in the usage of virtual personalities or fabricated spokespersons to advertise and sell products. An integrative plan utilizing digital marketing techniques and methods is an effective strategy in captivating the savvy online consumer. This is an appropriate indication of the future whereby immersive and interactive virtual worlds will play an increasingly important role in the consumer's life. According to Casswell (2006), one of the most recent and overt examples of brand placement within Second Life revolves around the appearance of specially designed regions and islands for brands themselves. "Companies rent or buy space for their own islands, instead of merely leasing a site, and they are asking for increasingly sophisticated marketing research, which Second Life is positioned to provide" (p. 207). An emerging case study in the utilization of a virtual personality that comprises an affective and cognitive feedback system with the consumer is found in the chatbot for Subway sandwiches, which can be found in the virtual world called Whyville. This chatbot is a personified Subway's "marketing research indicated teen characters would be receptive to talking with a cartoon character about healthy eating habits" (p. 209). The chatbot succeeded by offering a meal and health tips and advice to Whyville teens, by directly answering consumer questions about different Subway food products, and offering prizes for

participation in Subway quests. This example of a virtual personality directly interacting with consumers to influence product contexts, attitudes, and purchasing behaviors reflects Steuer's observation predicting that marketing in virtual environments will be far more effective than marketing in the real world. He states "the ability to affect experience of the world will be the differentiator for success in competitive markets. In an increasingly global market environment, where product differentiation based on features and pricing is at best a short-term strategy, marketing in VEs as defined here will be the long-term strategy of choice. The viability of marketing in VEs and the ability of marketing efforts in VEs to affect the experiences of the world. Affecting real and individual customers in the real world is what any company is seeking from their advertising efforts, the place where advertising and promotion is most effective is where they will choose to invest" (2009, p. 51) [27, 28].

5 Conclusion

Immersive Marketing and Advertising Information Systems (IM&AIS) represent a significant paradigm shift in the marketing landscape. By leveraging cutting-edge technologies like Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI), IM&AIS create highly interactive and engaging experiences for consumers. These experiences foster deeper brand connections, enhance customer engagement, and personalize advertising campaigns.

However, the widespread adoption of IM&AIS hinges on addressing critical challenges. Privacy concerns regarding extensive data collection necessitate the development of robust data security measures and clear consumer privacy regulations. Additionally, IM&AIS need to seamlessly integrate with traditional marketing strategies to maximize their effectiveness.

The future of IM&AIS is bright, with the potential for virtual influencers to play a prominent role in immersive marketing campaigns. As technology continues to evolve, IM&AIS will undoubtedly revolutionize the way brands connect with consumers and create lasting brand loyalty.

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Metaverse for Education Information Systems: A Systematic Literature Review

Andreia de Bem Machado, Maria José Sousa, Antonio Pesqueira, and Alvaro Rocha

Abstract This paper presents a systematic exploration of the role of the metaverse in transforming educational information systems, using a comprehensive bibliometric analysis of academic literature from the Scopus database. The metaverse, a digital construct where real and virtual worlds converge, is increasingly recognized for its potential to revolutionize learning environments. This study aims to describe the nature of the metaverse and its ability to innovate educational information systems through the possible integration of technologies and educational processes. By synthesizing current research, this paper reveals the transformative potential of the metaverse in various fields, with a particular focus on its implications in education. The methodology includes bibliometric analysis and systematic literature review, using citations and word co-occurrence to map the influence of studies, authors, and journals, and to identify relationships between key concepts and themes. The keyword-guided search yielded 116 relevant articles, from which data on publication details, institutional affiliations, and thematic trends were extracted and analyzed using bibliometric software. The findings underscore the capacity of the metaverse to foster immersive, interactive, and personalized learning experiences, facilitate international scholarly collaboration, and enhance continuous educational professional development. Despite its promise, the study also highlights challenges,

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including the need for secure, ethical, and user-centered technological frameworks, and calls for multidisciplinary research to address these issues. Therefore, this paper contributes to the scholarly discourse by offering a multidimensional view of the role of the metaverse in education, underscoring the need for continued innovation and policy-driven research to realize its full educational potential. The insights gained lay the groundwork for future investigations aimed at bridging existing gaps and harnessing the metaverse's capabilities in creating dynamic and inclusive educational landscapes.

Keywords Metaverse · Virtual environment · Education · Interactivity · Learning

1 Introduction

In the swiftly transforming domain of digital technology, the emergence of the metaverse is redefining the convergence of reality and virtuality, marking a paradigm shift in various sectors, particularly in education. The metaverse, a term that encapsulates the fusion of real and virtual worlds, facilitates an array of social, commercial, and cultural interactions in an immersive setup. This groundbreaking concept transcends the conventional digital frontier, positioning itself as an innovative educational paradigm. The inherent ability of the metaverse to blend real-world elements with virtual components unlocks unprecedented prospects for educational information systems, heralding an era of learning environments that capitalize on technology to enrich and elevate educational experiences [2–4].

The academic discourse accentuates the integration of avant-garde technologies such as blockchain, Artificial Intelligence (AI), and Virtual Reality (VR), Augmented Reality (AR) within the metaverse framework. This integration is fundamental in unlocking the metaverse's full potential, notably in fostering seamless, secure, and immersive user experiences. The metaverse's impact on business models, marketing strategies, and consumer behavior is increasingly gaining traction, with literature underscoring its role in facilitating innovative customer engagement, brand enhancement, and collaborative value creation [3, 4, 8].

A diverse array of theoretical frameworks and methodologies are employed to scrutinize the intricate nature of the metaverse. Among these are qualitative metasynthesis, which amalgamates and interprets findings from various studies to offer a comprehensive perspective of the metaverse's theoretical and practical aspects [4, 8, 9].

The extant literature lays a foundational understanding of the metaverse's transformative potential across a spectrum of industries and sectors. However, it also delineates a complex, multifaceted research terrain that necessitates a concerted effort from academia, industry, and policymakers to fully leverage these technologies in a manner that is secure, ethical, and oriented around user needs. Recent scholarly endeavors underscore the burgeoning significance of the metaverse across myriad fields, with a specific focus on its ramifications in medical education, healthcare

systems, and broader educational paradigms. These studies employ a heterogeneous mix of methodologies, including qualitative meta-synthesis, systematic literature reviews, bibliometric analyses, and hybrid SEM-ML learning models, providing a multidimensional perspective on the metavers's potential and challenges [8–10].

This paper embarks on a journey to methodically dissect and articulate the influence of the metaverse in reforming educational information systems. A rigorous systematic review of literature sourced from the Scopus database forms the cornerstone of this study. This investigation pivots on critical inquiries: What is the quintessence of the metaverse, and how can educational information systems be revolutionized through its capabilities? This exploration is predicated on the premise that the metaverse, by amalgamating virtual features with the tangible realm of classrooms, harbors the potential to significantly bolster and metamorphose the educational process.

To delve into the academic discourse on the metaverse, information systems, and education, this paper employs bibliometric analysis, recognized as a quantitative and statistical approach to assessing the production, publication, utilization, and dissemination of scientific knowledge. This analysis leverages statistical techniques to evaluate and monitor the progress of specific fields of study by categorizing data such as citations, collaborations, author affiliations, keywords, and discussed topics. The methodologies utilized in this study encompass citations and co-occurrence of words, aiming to estimate the influence of studies, authors, and journals in the field and to map and establish connections between words and concepts. The decision against employing bibliographic coupling is justified by its significance in analyzing publications within the same timeframe, whereas this work evaluates publications spanning from 1978 to 2019.

Subsequently, pertinent information such as the title of the article, authors, affiliating institutions, country of the institution, year of publication, keywords, title of the journal, and references were meticulously collated. The analytical phase involved the use of bibliometric software VOSviewer and the Bibliometrix package (version 2.2.1.), a tool from the free software R. This phase culminated in the visualization and evaluation of data provided by the Scopus platform, including authors, teaching and research institutions, and research areas that produced the most knowledge, alongside the language in which the articles were penned.

The main results and analyses of the data are presented in the following section, offering a comprehensive exploration of the burgeoning intersection between the metaverse, educational information systems, and the broader academic landscape.

The forthcoming sections of this paper are dedicated to presenting an exhaustive analysis of the present landscape of metaverse applications in the educational sector. This analysis delves into the modalities through which this nascent technology can be harnessed to cultivate dynamic, interactive, and efficacious learning environments. Through this exploration, the paper aspires to lay a foundational understanding of the metaverse's role in educational information systems, thereby paving the path for future innovations in this exhilarating and rapidly progressing domain.

2 Contextualizing the Metaverse: An Analysis of Its Current State and Implications

Conceptualized as an immersive and interconnected digital environment, the metaverse extends its utility to areas such as telesurgery and telemedicine, leveraging the strengths of blockchain and explicable AI to improve data security, transparency, and precision in clinical decision-making. The integration of IoT, blockchain, and AI under the metaverse framework is particularly prominent in the in some industries, where it plays a critical role in improving certain operational processes and addressing concerns related to data security and privacy [10–12].

Research highlights the integration of advanced technologies such as blockchain, AI, and VR/AR within the metaverse infrastructure. This integration is critical to harnessing the full capabilities of the metaverse, particularly in promoting seamless, secure, and immersive user experiences. The influence of the metaverse on business paradigms, marketing strategies, and consumer behavior is increasingly recognized, with literature suggesting that the metaverse paves the way for innovative approaches to customer engagement, brand enhancement, and collaborative value creation [11, 12, 15].

A variety of theoretical frameworks and methodologies are used to explore the complex nature of the metaverse. These include qualitative meta-synthesis, which synthesizes and interprets findings from different studies to provide a holistic view of the theoretical and practical dimensions of the metaverse. Systematic literature reviews and bibliometric analyses contribute an overarching perspective of the research landscape, identifying dominant themes, trends, and knowledge gaps. In addition, hybrid SEM-ML approaches merge structural equation modeling with machine learning algorithms to provide detailed insights into user perceptions and intentions, particularly in educational and healthcare settings [12, 15, 17].

The existing literature provides a foundational understanding of the transformative potential of the metaverse across industries and sectors. However, it also outlines a complex, multifaceted research terrain that requires a collaborative approach among academia, industry, and policy makers to fully harness these technologies in a manner that is safe, ethical, and focused on user needs. Recent scholarship highlights the growing importance of the metaverse across multiple domains, with particular attention to its impact on medical education, healthcare systems, and broader educational frameworks. These studies use a variety of methodologies, including qualitative meta-synthesis, systematic literature reviews, bibliometric analyses, learning models, to provide a multidimensional view of the opportunities and challenges of the metaverse [15, 17, 18].

Future research is essential to fill these gaps, with a focus on developing robust, user-centered, and ethically sound technological infrastructures. This endeavor requires a multidisciplinary approach that integrates insights from information technology, health care, education, law, and ethics to develop solutions that are not only technologically competent, but also socially responsible and ethically sound. There

is also an urgent need for policy-driven research to establish guidelines and standards for the application of these technologies in sensitive areas such as healthcare and education [17–19].

3 Revolutionizing Educational Paradigms: Integrating the Metaverse

While there is widespread recognition of the potential of the metaverse, the literature also highlights various limitations and future research directions. From an empirical standpoint, there's an urgent need for studies that substantiate the theoretical constructs and conceptual frameworks outlined in scholarly discourse. This includes conducting longitudinal studies to measure the lasting effects of the metaverse in different sectors [18, 19, 21].

Technological hurdles, particularly issues related to interoperability, privacy, and user security in the context of the metaverse, continue to be prevalent themes. Overcoming these challenges is critical to the broader acceptance and sustainable expansion of the metaverse. In addition, ethical and societal considerations demand attention, as the impact of the metaverse on societal norms, ethical codes, and human behavior remains largely unexplored. Future research should seek to elucidate these implications and formulate principles to guide the responsible development of the metaverse [5, 24].

The current scholarly discourse on the metaverse underscores its escalating importance and capability in various industries. However, realizing this potential will require a unified effort to address the challenges and gaps outlined, requiring an interdisciplinary approach to research and collaboration between academia, industry, and policy architects. In the realm of higher education, academic research is revealing a complex and evolving landscape shaped by metaverse technologies. These studies illuminate multiple facets of how such technologies are redefining educational experiences, particularly in higher education contexts [5, 24, 32].

Metaverse technologies significantly support distance education by creating dynamic online classrooms, fostering communication, and facilitating immersive learning experiences. This is particularly evident in the creation of engaging gamification elements within the educational process. In addition, the metaverse offers distinct opportunities for embodied learning experiences, potentially enriching arts and humanities curricula beyond conventional methodologies and fostering unprecedented levels of student engagement [24, 32, 38].

In the specific context of language education, blended English learning through metaverse platforms has been identified as a significant enhancer of academic achievement, attributed to increased learner engagement in immersive virtual environments. In addition, the metaverse contributes to the realization of equitable educational opportunities, in line with the fourth sustainable development goal. While the metaverse advances higher education by engaging young learners and enriching

immersive learning, there are barriers to its implementation, including technological, infrastructural, and pedagogical barriers. In addition, the metaverse, while beneficial, has risks and implications, particularly in terms of user experience and institutional adaptability. As a result, ongoing research, implementation, and monitoring are essential to ensure a more relevant and effective educational process in higher education [32, 38, 40].

Preliminary findings suggest that self-efficacy and subjective norms positively influence university students' perceptions and perceived usefulness of meta-educational technologies. Furthermore, the use of augmented reality in videoconferencing in higher education is significantly influenced by factors such as performance expectancy and hedonic motivation. The intersection of the metaverse, education, and educational information systems emerges as a rich breeding ground for innovation in learning methodologies. The literature reviewed signals a trend toward immersive, interactive learning environments and emphasizes the importance of user-centered design and satisfaction in the adoption of educational technologies. Despite the promising prospects, the field calls for further empirical research to fully exploit the multiple possibilities of the metaverse in education. The dynamic nature of the field requires agile, responsive research approaches to keep pace with technological advances and evolving educational needs [38, 40, 44].

In exploring the metaverse in education and educational information systems, a number of scholarly sources have been methodically reviewed to ensure a thorough understanding of this domain. Key findings from the literature reveal a dynamic interplay between metaverse technology and educational methods. Educational perspectives within the metaverse are characterized by their interactivity, immersion, and multiplicity, using foundational technologies such as VR/AR to augment formal education, informal learning, and vocational training [40, 44, 50].

From the perspective of technological evolution in education, the integration of the metaverse represents a significant evolution from traditional educational paradigms. It leverages technologies such as big data, AI, and Internet of Things (IoT) to cultivate innovative, personalized teaching and learning environments. User satisfaction is identified as a critical factor in the adoption of metaverse systems in educational contexts, underscoring the need for a user-centered approach to deploying these technologies [44, 50, 54].

The incorporation of the metaverse as a digital tool in hybrid educational models underscores its potential to enrich learning experiences through technology-enhanced environments. Recent studies suggest that the metaverse has the ability to transform traditional teaching methods into immersive, interactive learning experiences, with applications that span multiple educational sectors. In addition, effective integration of metaverse technologies into education requires a thorough understanding of user acceptance, satisfaction, and the educational value provided by these immersive platforms [50, 54].

The reviewed studies employ a variety of theoretical and methodological frameworks, including structural equation modeling and machine learning, to assess the impact and effectiveness of metaverse applications in educational contexts. The

variety of methodologies reflects the complexity and multidimensional nature of education in the metaverse [21, 22, 26].

While these methodologies provide rich insights into user behavior and system effectiveness, they also underscore the need for ongoing refinement and adaptation to adequately meet educational goals and user expectations.

In terms of future research directions, the existing body of research highlights the transformative potential of the metaverse in education. However, it also highlights the need for further exploration in areas such as optimizing the user experience, advancing the technology, and developing pedagogical frameworks tailored to virtual learning environments [26, 28].

Future studies should focus on the longitudinal effects of metaverse technologies on learning outcomes, the scalability of educational metaverse platforms, and the integration of adaptive learning mechanisms to accommodate different learner profiles. The exploration of metaverse applications in education presents a landscape full of opportunities and challenges. The integration of the metaverse into educational settings is being scrutinized for its potential to revolutionize traditional pedagogies, albeit with emerging challenges that require extensive research and development [26, 28, 29].

Collectively, the literature emphasizes the transformative implications of integrating the metaverse and AI into healthcare and education. While the promise of these technologies in enhancing data security, transparency, and immersive experiences is evident, the research also outlines challenges associated with their implementation and integration. These include ensuring data privacy, addressing the scalability of solutions, and formulating frameworks that foster trust and reliability among users. The studies highlight the critical need for interdisciplinary research and collaboration to address these challenges and realize the full potential of these converging technologies to revolutionize healthcare and education [28, 29, 34].

4 Future of Higher Education

The range of potential applications for metaverse technology in higher education is both broad and promising, with the capacity to fundamentally alter the educational landscape. One notable application is the development of immersive virtual classrooms that transcend physical boundaries and allow students from different locations to converge in a unified, virtual space. This advancement not only increases the accessibility of education, but also fosters a sense of community and collaboration among students who might not otherwise have the opportunity to interact [29, 34, 35].

In the realm of experiential learning, metaverse platforms are particularly powerful. Medical students, for example, can use these platforms to simulate surgical procedures in a risk-free environment to hone their skills. Similarly, history students could travel through ancient civilizations in a three-dimensional format, providing a more vivid and interactive educational experience compared to traditional learning methods. Personalized learning is another important frontier where the metaverse has

immense potential. Through the use of AI, avatars or agents, students can be guided through customized learning paths that address their unique needs and learning preferences. This tailored approach is critical to addressing the diverse range of learning needs and paces, making education more inclusive and effective [34–36].

In terms of research and collaboration, the metaverse is a powerful facilitator of international scientific collaboration. Researchers from different corners of the globe can join together in virtual laboratories, sharing resources and insights instantly, potentially accelerating scientific breakthroughs and innovation.

Looking further into the future, it's conceivable to imagine entire university infrastructures within the metaverse. Such virtual campuses could host a range of academic and social activities, providing a full university experience to individuals who may be prevented from attending in person due to financial, physical, or geographical constraints [35–37].

In addition, the integration of AR and VR within the metaverse could greatly enhance field trips and hands-on learning projects. For example, students studying environmental science could virtually explore and analyze various ecosystems, eliminating the need for physical travel, thereby reducing costs and carbon footprints [36, 37, 39].

The metaverse also offers significant opportunities for continuous learning and professional development. Professionals can participate in continuous educational experiences, updating their skills and knowledge in tandem with dynamic industry landscapes, all without resorting to traditional classroom environments [37, 39, 41].

Overall, the potential applications and uses of metaverse technology in higher education are vast and revolutionary. They pave the way for immersive, personalized, and collaborative learning experiences and lifelong learning. As these technologies evolve, they will have a significant impact on the future of education, making it more accessible, engaging, and efficient [39, 41, 45].

5 Metodology

In order to analyse the academic production of studies on metaverse, information systems and education, we first opted to use bibliometric analysis. Considered a science, bibliometrics involves the quantitative and statistical study of the production, publication, use and dissemination of scientific knowledge from bibliographic databases [23]. Next, we systematically analysed the data collected from the ten most cited articles to answer the research question.

Using statistical techniques, bibliometrics makes it possible to evaluate and monitor the progress of fields of study by classifying data such as citations and collaborations, author affiliations, keywords, topics discussed, relevant topics and methods used [1]. As a result, it is possible to identify relevant aspects regarding the structure of the field, social networks and relevant topics for future research with quantitative rigour, according to the process presented in Table 1 [56].

Table 1 Description of the methodological process

Stage	Technical	Description
1	Research	a. What is the research question? b. Choosing the most appropriate bibliographical method (Table 2)
2	Compilation of data	a. Choosing (or building) the appropriate database and selection criteria (Tables 3 and 4) b. Filtering and exporting the articles with the highest number of citations (Table 5)
3	Analysing	a. Choice of bibliometric software (Bibliometrix package from R Software) b. Selection of information for publication
4	Bibliometric	a. Choosing the right method for visualisation b. Selection of the software to implement the visualisation of the results (Bibliometrix and VOSviewer)
5	Analysing	a. Description and interpretation of findings

Source Adapted from Zupic and Čater [56]

Table 2 Summary of bibliometric methods

Method	Description	Unit of analysis
Citations	Estimates the influence of documents, authors or journals through citation rates	Document, Author, Journal
Co-occurrence of words	Uses words to establish relationships when they appear in the same document	Word and concept

Source Adapted from Zupic and Čater [56]

Table 3 Inclusion and exclusion criteria for articles

N	Criteria	Reason for inclusion/exclusion
Inclusion criteria		
1	Publications that study the metaverse or virtual reality	Enable each theoretical concept covered to be understood and described individually
2	Publications that study the relationship between "Metaverse" OR "virtual reality" AND "Information Systems" together	Make it possible to understand the interdependencies and relationships between the theoretical concepts covered
3	Publications with an emphasis on education	Provide an understanding of the theoretical contributions made by academics in the field of education
4	Articles only	Allow rigorous arguments and theoretical foundations scientifically established
Exclusion criteria		
1	Proceedings of scientific events (proceedings papers), working papers, ebooks and book chapters among others	It is not the aim of this work to evaluate articles that have not yet been finalised or published by high-impact journals

Source Authors (2024)

Table 4 Description of search terms and results on 22 January 2024

Database	Scopus
Search line	"Metaverse" OR "virtual reality" AND "Information Systems" AND "Education"
Filters	Article
Articles	116
Sample analysed	116

Source Authors (2024)

Table 5 10 most cited articles in the area

Year	Article	DOI	Total citations
2014	Ventola [49]	NA	731
2011	Ballouard [7]	https://doi.org/10.1371/journal.pone.0023152	153
2017	Lv [31]	https://doi.org/10.1016/j.neucom.2016.07.078	117
2023	Xi [53]	https://doi.org/10.1007/s10796-022-10,244-x	114
2022	Almarzouqi [4]	https://doi.org/10.1109/ACCESS.2022.3169285	113
2010	Vankipuram [48]	https://doi.org/10.1016/j.jbi.2010.05.016	96
2002	Shine [43]	https://doi.org/10.1097/00001888-200,201,000-00,021	83
2014	Khanal [25]	https://doi.org/10.1016/j.jbi.2014.04.005	69
2011	Law [27]	https://doi.org/10.1016/j.apacoust.2011.02.003	65
2004	Diefenbach [16]	https://doi.org/10.2196/jmir.6.1.e3	56

Source Authors (2024)

The first stage consisted of defining the following research question1) what is metaverse? How can information system for education be developed using the metaverse? In preparing the research question, the feasibility of different possible methods for analysing bibliometrics was assessed, taking as a reference the potential to deliver results and units of analysis, as shown in Table 2.

The methods applied in this study were: citations and co-occurrence of words. These methods were chosen to estimate the influence of studies, authors and journals in the field of study and to map and establish relationships between words and concepts. The choice not to apply the bibliographic coupling method is justified because its use is significant for analysing publications in the same time frame [56], but this work evaluates publications between 1978 and 2019.

In the third stage, keywords were defined, the database searched and the filters used (Tables 3 and 4). The joint search was defined by the expressions "Metaverse" OR "virtual reality" AND "Information Systems" AND "Education". The database chosen was Scopus. The search was limited to scientific articles in fields of study related to business and administration (Tables 3 and 4). In order to understand the field as a whole, no time limit was set.

The Scopus database was chosen because it is one of the oldest and most reliable indexers in terms of the scope and quality of the journals incorporated [33].

From the search line applied to the Scopus database (Table 4), a total of 542 records were generated (base date: 22 January 2024). Of these, 426 articles were excluded from the analysis because they were classified as Proceedings Paper, ebook and book chapter, resulting in a sample of 116 articles. The following information was then collected: title of the article, authors, institutions to which the authors were affiliated on the date of publication, country of the institution, year of publication, keywords, title of the journal, references used.

The third stage consisted of defining the software to be used for the analysis: the bibliometric software VOSviewer [47] and the Bibliometrix package (version 2.2.1.), a tool from the free software R [6]. The fourth stage consisted of visualising and evaluating the information provided by the Scopus platform itself, such as authors, teaching and research institutions, research areas that produced the most knowledge, and the language in which the articles were written. The data was then processed and exported (Bibliometrix and VOSviewer) for data analysis and the construction of bibliometric maps, which allowed for graphic visualisations. The following section presents the main results and analyses of the data.

6 Analysing the Data

Overall, scientific production on "Metaverse" OR "virtual reality" AND "Information Systems" AND "Education" as a whole shows an annual growth rate of 10% in 2023. The field in question shows a quantitative evolution that can be categorised into three stages (1994–2002; 2003–2017; 2018–2023), as shown in Fig. 1.

The first stage contains articles published between 1994 and 2002, with sparse publications, no more than one per year. We also identified years in which there were no publications on the subject, indicating a field of research still in its infancy.

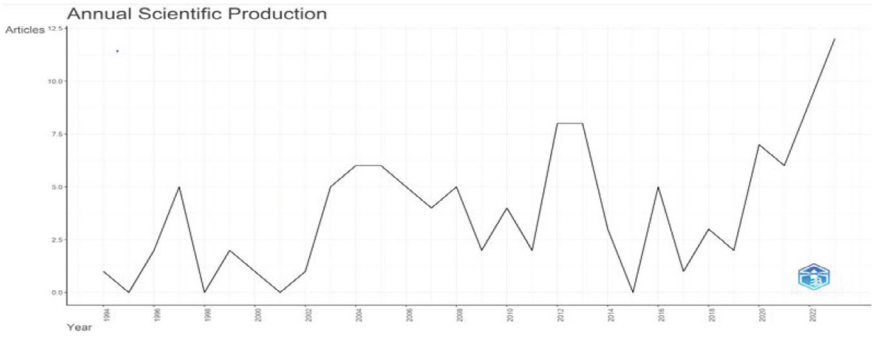

Fig. 1 Evolution of the annual scientific production of articles between 1994 and 2023. *Source* Adapted by the authors from the Bibliometrix package (2024)

Publications began with the advent of the internet in mid-1994, when the first virtual environment, AlphaWorld, was created with the aim of providing an immersive environment, connecting the whole world [13]. The first published in 1994, found in the Scopus database, deals with explaining improvements to technology transfer for economic competitiveness, education and national security; and providing a fundamental part of the basis for the White House's National Information Infrastructure [30].

In the second stage, between 2003 and 2017, publications occurred more frequently, with an average of five articles per year. It is possible to infer that this was due to the launch on 23 June 2003 of the immersive platform Second Life, presented by its founder Philip Rosedale, from the company Linden Lab, as a 3D environment capable of simulating real human social life through avatars [20].

The third stage took place between 2018 and 2023, with a timid publication in 2018 with three published articles and a significant increase in 2023, with twelve publications in the area. In 2018, another Metaverse milestone was the release of the film Ready Player One, directed by Steven Spielberg. The OASIS is the digital universe where much of the action takes place. In 2021, Facebook announced its goal of becoming a "metaverse company" [14].

With regard to the four main research areas that study metaverse, education and information systems, according to the Scopus classification, the areas that produce the most are: Computer Science (50), Medicine (41), Social Sciences (32), Engineering (20).

According to Zupic and Čater [56], within the selected universe and method, it is possible to evaluate the countries with the most citations in the area and the most cited words, which can be considered important for science and for that field of research [56]. Thus, the majority of articles produced are written in English (96%), with the remainder (4%) written in Chinese (2 articles), Russian (2), Czech (1). In this scenario, the country with the most scientific production on the subject of metaverse, education and information systems was the USA, with 94 publications in the area, and in second place was China, with 31 works in the area, as shown in Fig. 2.

It is possible to identify that there is no reference author in the area, as each has published 2 documents on the subject of the research, as shown in Fig. 3.

Figure 4 shows the co-occurrence map of keywords, which makes it possible to establish relationships between the keywords used and build a conceptual structure about the field being analysed. The result of this network is a semantic map that makes it possible to identify the cognitive structure of the field [56]. The map shows 9 words that had at least 37 mentions out of a total of 1,574.

Figure 4 shows the two groupings of words most pertinent to studies on the metaverse, information systems and education together. The first of these—green—has the main words "virtual reality" (102), "education" (30), "students" (20) and "e-learning" (22). It is possible to infer that the studies that use these words the most focus on virtual reality, which is consistent with the keywords used for the search in the Scopus database. Understanding aspects related to the performance of education models and the application of information systems in education to quality student education.

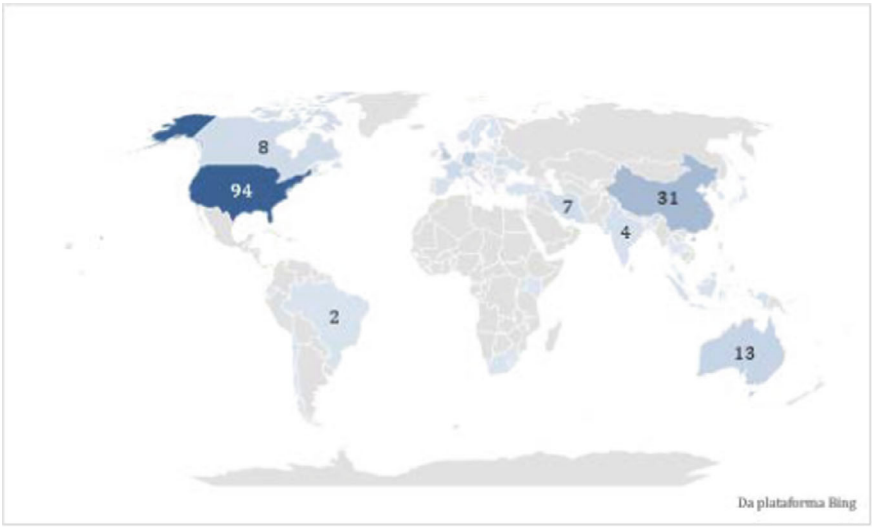

Fig. 2 Publication frequency by country in the Scopus database. *Source* Adapted by the authors from the Bibliometrix package (2024)

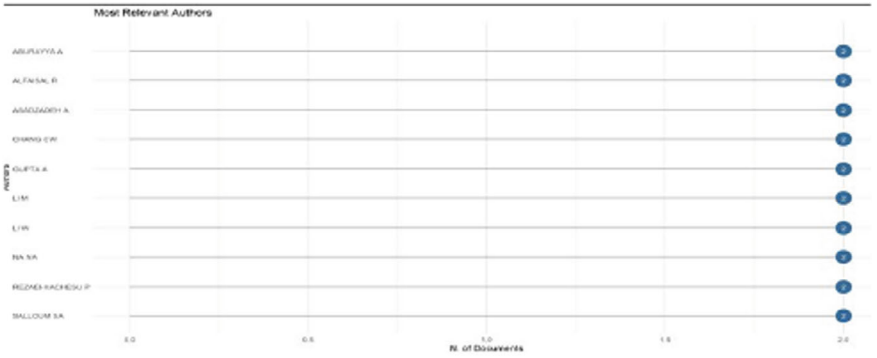

Fig. 3 Most relevant authors Scopus. *Source* Adapted by the authors from the Bibliometrix package (2024)

The second cluster with the strongest links between the nodes is red and has the words article (44), Human (34), Medical information system (26), Internet (20) and Priority journal (21). It can be inferred that the focus of the articles in this cluster is on realising the impact that certain information systems can have on applications in the medical field.

The 10 most cited articles in the area are listed in Table 5.

Of the 10 articles that made up the corpus of analysis, two were systematic literature reviews and eight were empirical studies using a questionnaire. Of these articles, 8 answered the study's problem. After the researchers read and analysed the articles,

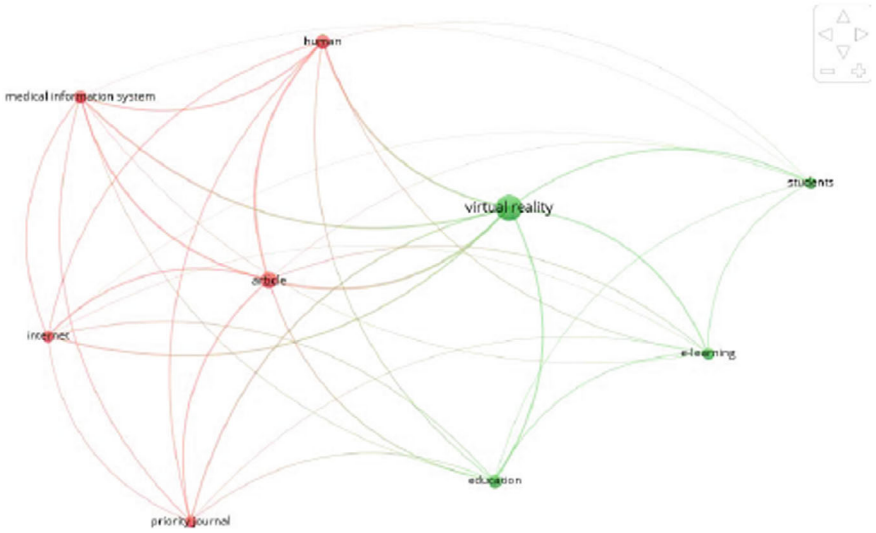

Fig. 4 Word co-occurrence analysis map. *Source* Adapted by the authors from the Bibliometrix package (2024)

they identified some themes that stood out in the main problem of this research: How to develop an information system for education using the metaverse? which will be discussed and answered below.

The metaverse is an environment that aims to create an intuitive form of human–computer interaction through a space for exchanging information and knowledge in a virtual environment. Participants in the virtual world can carry out tasks that are similar to or even incapable of being done in the real world. Thus, such virtual reality applied to an information system with data stores that enable the resolution of problems in the educational world can be developed in different ways, which will be described below by analysing the eight articles.

In this scenario, according to Ventola [49], the information systems developed for medical education using the metaverse are the doctor networking sites that include QuantiaMD, Doctors' Han- gout and Doc2Doc. These sites are designed for doctors to submit their credentials to a site concierge, recreating the intimacy of a "doctor's room" in an online educational environment, which in this research is called the metaverse. In this context, the information system understood in this research is any system that processes information and produces results for a specific purpose in which each of its systems is part of an organisation's automated problem-solving system [42].

For Ballouard et al. [7], the Internet can be used as a pedagogical tool, as it is used by people to access scientific information. So this information system (Internet) can be used by a student interested in a particular topic as the fastest, richest and most convenient source of information. In this system he can gather data from this virtual environment for his learning. Thus, in order to develop an information system for

education using the metaverse, it is necessary to use the internet as a pedagogical tool for data collection.

Lv et al. [31], explains that in order to develop an information system for education using the metaverse, a combination of geographic information systems and virtual reality technology (metaverse) must be realised. Thus, in the article analysed, a VRGIS platform was created based on a network environment that establishes interactive 3D multimedia on the Internet to describe three-dimensional objects and their behaviour.

Xi et. al [53], the development of an information system for education with the use of the metaverse is created through information technologies that allow the human–computer interface to create an online environment that promotes learning.

Almarzouqi et. al [4], the development of an information system for education using the metaverse must be created so that users perceive virtual objects and multi-user communication in virtual space. This space must create an environment that combines the contemporary behaviours of all objects, avatars that symbolise their users, and their interactions, such as avatar-object, object-object and avatar-avatar, allowing for greater interaction and interactivity between teachers and students.

Vankipuram et al. [48], explain that in order to develop an information system for education using the metaverse in the medical field, it is necessary to allow the user to interact with the virtual environment. Thus, simulations should be carried out using conventional computer interfaces such as mouse and keyboard. The main aim of these environments is to help future doctors familiarise themselves with the procedures and tools and to learn the magnitude of the force to be applied to the tools in various types of procedures during surgery.

Khanal et al. [25], discusses that collaborative virtual environments in the medical education field should allow the user flexibility to take on different roles such as doctor, patient, trainer, internship. Such a virtual medical learning environment based on the metaverse should provide Advanced Life Support in Cardiology.

Diefenbach and Brian [16], explain that in order to develop an information system for medical education using the metaverse in prostate surgery, it is necessary to create rooms in a virtual health centre (i.e. reception area, library, doctors' offices, group meeting room) to organise the information that will enable meaningful learning for future doctors.

Of the eight articles analysed, five were about education in the medical field. Thus, it can be concluded that each educational area has a specificity that must be studied and analysed in order to create an information system for education using the metaverse. The metaverse can offer enhanced immersive experiences with more interaction and interactivity between students and teachers, providing meaningful learning for students.

7 Final Considerations

The main aim of this article was to map out how an information system for education can be developed using the metaverse in the Scopus database. A total of 116 articles were identified and adhered to the focus of this article. To achieve this objective, a bibliometric analysis and a thematic analysis of the 10 articles with the highest number of citations were carried out. Of the articles analysed, 8 answered the research question.

It was found that the interest of researchers in an information system for education using the metaverse is still timid, as there is no reference author on this subject.

The "countries" with the most publications in the area of information systems for education using the metaverse were the USA with 94 publications in the area and China in second place with 31 works in this area.

In conclusion, to answer the research question a thematic analysis of the articles was carried out and it was identified that the metaverse is a digital space accessible through a virtual environment that can be developed with the organisation of systems and information for education with tools that can provide interaction and interactivity between teachers and students that guarantee meaningful learning. Thus, the metaverse can change the teaching–learning process from face-to-face to virtual environments, allowing interaction and collaboration between students and teachers.

For future research, the aim is to map out how the metaverse can serve as a tool for sustainable technological innovation with the application of sustainable development objectives in the context of higher education.

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Unraveling the Challenges and Drivers of Metaverse E-Commerce: A Thematic Analysis

Najmul Hasan, Yukun Bao, and Atika Qazi

Abstract With the increasing popularity of the metaverse, e-commerce has the potential to hold an integral role in the virtual marketplace. Leading tech firms and numerous stat-ups are making a significant contribution to exhilarate the metaverse in their business. Despite this, there is a dearth of scholarly research on e-commerce related to the metaverse. This study aims to systematically review the primary factors that influence the metaverse's adoption in the e-commerce industry, including the challenges faced, and look into a novel consumer-centered adoption model. This study systematically conducts a thematic analysis of 27 scholarly published articles. We searched Scopus and the Web of Science Core Collection for relevant published papers up to December 2023. The analysis uncovers the main emerging themes and challenges of adoption in the realm of metaverse e-commerce. The thematic analysis uncovers a total of 35 sub-themes and 8 noteworthy emerging themes related to the adoption of metaverse e-commerce: responsiveness system quality, perceived informativeness, perceived virtual marketplace, avatar influencer, hedonic value, accessible metaverse infrastructure, digitalized consumer mindset, virtual consumer engagement. Moreover, this study also uncovers 16 adoption issues for designing metaverse e-commerce applications. The novelty of this study lies in the development of a conceptual framework that reveals how metaverse providers might implement adoption factors considering the issues that arise in concurrent metaverse e-commerce. The paper concludes by providing a future research agenda for more investigations.

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1 Introduction

The concept of "Metaverse" gained popularity after it was introduced by Neal Stephenson in his cyberpunk novel Snow Crash back in 1992 [1]. Since then, there has been a growing interest in this idea across various industries including e-commerce [2]. In recent years, numerous researchers have explored several challenges and opportunities of metaverse technology in the e-commerce domain [3–5]. Metaverse technologies have significance for enhancing the potential of e-commerce businesses by offering a suitable platform, securing financial transactions, and engaging consumers through virtual experiences [6]. Considering the significant increase in scholarly interest in the metaverse, it is of utmost importance to comprehend e-commerce inside the metaverse.

Requirements for unraveling intelligent e-commerce systems have grown significantly in recent years for business innovations that enhance business values. The research focused on several key areas of interest in metaverse e-commerce studies. These included investigating the effects of augmented reality (AR) and virtual reality (VR) on consumer perceptions while e-commerce shopping [7], examining how the technical features of the metaverse impact virtual presence [8], and assessing the degree of consumer engagement achieved through the use of AR or VR [9]. However, recent research indicates that the applications of metaverse studies are limited in general [10]. Hence, there are call for further studies from a digital-enabled intelligent business standpoint about the conceptualization of drivers in metaverse e-commerce, focusing on their applications design issues, and future innovations [10–12]. To facilitate the expansion of this area, it is of the utmost importance to conceptualize innovative metaverse e-commerce drivers. To address the above call, this study set three primary objectives for this thematic analysis: (a) unraveling the major drivers, (b) applications design issues for the metaverse in the field of e-commerce, and (c) explore innovative consumer-centered adoption models in metaverse e-commerce. This study focusses mainly on exploring the long-term implications of the metaverse beyond its immediate usages in satisfying the demands of the e-commerce industry. The intention is to identify metaverse adoption hurdles and potential drivers to contribute new research that will encourage the advancement of this field.

The majority of the research focuses on user adoption and the development of virtual e-commerce applications rather than providing additions to generalized comprehension for user adoption. For example, prior literature concentrates on collecting data through surveys or suggesting further research using traditional information systems (IS) frameworks (i.e., technology adoption model (TAM)) [13]. Rathore [14] investigated the complex relationship between transformations in digital technology, including VR and AR, and their impact on the e-commerce business.

Moreover, prior reviews of the metaverse e-commerce literature have often used hierarchical classifications to develop virtual commerce applications [15]. Riar et al. [16] reviews and synthesizes how and where AR is used in virtual purchasing, what theories and technical aspects are often analyzed, and what cognitive and behavioral factors of AR have been identified. Existing review papers on metaverse e-commerce do not primarily concentrate on emerging IS drivers, particularly those that relate to end-user-centric adoption factors. However, it is crucial to comprehend the drivers used for metaverse e-commerce and the adoption challenges. From the IS standpoint, it is evident that there is a significant gap in the research regarding the identification of user adoption factors (themes) and metaverse e-commerce adoption issues by marketers of metaverse e-commerce. The technical issues and associated adoption themes in this field have not been adequately addressed, and there is a lack of a solid theoretical foundation to guide further exploration. Therefore, this study intend to address the following research questions (RQ):

RQ1: *What are the major challenges for designing metaverse e-commerce applications?*

RQ2: *What are the key drivers for consumer-centered adoption models?*

RQ3: *What might be a potential consumer-centered metaverse e-commerce adoption model from the IS perspective?*

Therefore, this study applied a bottom-up strategy to systematically examine and analyze existing literature using a qualitative thematic analysis technique [17]. This conceptualization is crucial for providing metaverse e-commerce designers, industry practitioners, and end-users with improved insights for their future inventive breakthroughs in this specific domain.

Through this thematic analysis, we provide four major contributions to the existing body of research on metaverse e-commerce. First, we have conducted a systematic literature analysis of 27 published articles up to December 2023 to identify shortcomings in the existing body of knowledge. Second, through this analysis, we broaden upon Riar et al. [16] review on AR in the realm of virtual shopping that draws attention to the importance of leveraging a more detailed conceptualization of the metaverse within the context of e-commerce. Third, the review highlights the knowledge architecture and up-to-date hot topics of metaverse research in the setting of e-commerce, therefore establishing a few umbrella themes for this area of study. Finally, industry practitioners can utilize the identified themes and issues to accelerate themselves in a simulated digital-enabled intelligent e-commerce operation that has the potential to reshape their business.

The paper is set up in the following structure. The following section presents the methodology details, followed by the study's findings. subsequently, we proceed to discuss our findings and provide the corresponding theoretical and practical implications. Conclusions, limitations, and future research avenues are detailed in the last segment of this paper.

2 Methodology

We conducted a comprehensive analysis of the existing literature on the metaverse and its relationship with e-commerce. We aimed to get a deeper understanding of the factors that contribute to the success of metaverse e-commerce adoption and the challenges associated with designing applications for this purpose. This enabled us to systematically assess the sampled articles and logically comprehend them [15]. To achieve this objective, we used the systematic literature review (SLR) method because of its capacity to provide thorough and reliable findings that are relevant to both theoretical and practical aspects. This method ensures consideration of the needs of practitioners and the specific settings in which they operate [16]. In a nutshell, SLR comprises three fundamental components: retrieving the data, analyzing the retrieved articles, and synthesizing them. Additionally, Ashraf et al. [18] posit that, the SLR offers an unambiguous method for analyzing the existing body of research, which makes it possible to replicate what was learned.

2.1 Setting the Review Boundaries

We searched Scopus and the Web of Science Core Collection for relevant published papers up to December 2023 to make sure that the research articles incorporated in this review possessed adequate quality. Which are deemed relevant and encompass articles from various academic fields. To be more precise, a Boolean search strategy was performed based on the search method outlined by Dieste et al. [19] to retrieve articles that included specified terms in the title, abstract, or keywords: (metaverse* OR e-commerce) AND (metaverse* AND electronic* AND commerce) AND (metaverse* OR electronic commerce). Furthermore, our search was limited to conference proceedings and journal articles across all domains. Furthermore, we limited the scope of our search to empirical research published in the "Article title".

The outcomes of searches from the initial search were retrieved 253 articles. After initially filtering the "title, abstract, or keywords", we eliminated the irrelevant papers which are not related to our RQs (excluded 196), and duplicate entries (excluded 8). Subsequently, we eliminated articles that were unrelated to the metaverse, and irrelevant to e-commerce (excluded 13) after a thorough screening of the titles, keywords, abstract, and full text. We excluded studies regarding books (excluded 2), and book chapters (excluded 8). It is worth noting that, we removed research that focused on domains other than business, management, and accounting. We additionally excluded papers that were not published in English (excluded 1). During the extraction phase, significant aspects are taken into account to identify articles that meet the inclusion criteria for relevant research. These criteria include factors such as the year of publication, metaverse e-commerce adoption, and challenges related to metaverse applications, etc. Finally, a total of 27 papers were included in the comprehensive review. The NVivo 12 Plus software package was used to code and cluster the 27

articles based on word similarities, figure out the sub-themes, and come up with overarching themes.

3 Results and Discussion

This SLR solidified the results of the 27 studies that satisfied our inclusion criteria. We employed Ashraf et al. [18] technique as a systematic approach for coding and analysing the data. The technique is highly suitable for systematic reviews due to its rigorous nature and focus on exploring emerging themes. The data analysis technique unfolds through six interconnected phases following Clarke, Braun [17]: familiarizing with data, generating initial code, searching the theme (sub-theme), reviewing the sub-theme, defining the theme (key theme), and reporting the key themes. This section presents the findings uncovered in two distinct inquiries. Initially, we provide a concise overview of the challenges arising in the metaverse e-commerce application design. Additionally, we identify the adoption factors that had not yet been identified in the earlier studies. Utilising well-established procedures employed in previous reviews [18], a thorough examination of each paper was conducted to create a comprehensive coding manual. Our analysis first identified a significant increase in the number of metaverse e-commerce studies, as seen in Fig. 1. Figure 1 indicated that there was a lack of emphasis on metaverse e-commerce research between 2018 and 2020.

Overall, the concepts explored in the selected studies were quite diverse. They covered topics such as the application of metaverse in e-commerce, factors influencing adoption, and the impact of these issues on business process re-design and implementation. The review has found sixteen issues that may arise during metaverse e-commerce application design and found eight key themes in which existing literature may be extended. (refer to Tables 1 and 2). In the next section, we will further explore these subjects.

Answering RQ1: *What are the major challenges for designing metaverse e-commerce applications?*

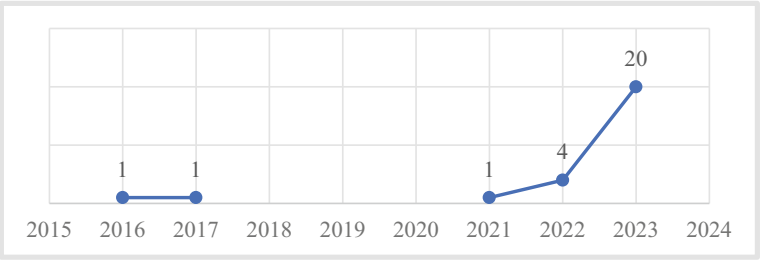

Fig. 1 Trend of metaverse e-commerce research

Table 1 Issues identified for designing metaverse e-commerce applications

Issues	Key references
AR-based online purchasing risk	[3, 7, 8, 16, 20, 21, 29]
Privacy (data)	[3, 4, 7, 9, 14, 16, 22, 24, 25, 30]
Virtual client designing	[9, 15, 22],
VR-driven shopping security	[3, 4, 6, 7, 9, 13, 14, 21, 22, 24–26, 31, 32]
Virtual product display quality	[3, 15, 16, 21, 26, 27],
Lack of hedonic benefits (fun and pleasure)	[3, 15, 16, 21, 27, 28]
Ineffective 3D online shopping environment	[15, 21, 31]
Mobile AR/VR	[3, 7, 8, 15, 21, 22, 26]
Improper virtual mall	[3, 15, 33]
VR-driven shopping agent	[15]
Transaction reliability	[9, 26, 31, 32]
Controlling fake reviews	[8, 20, 22, 27],
Blockchain interoperability	[3, 9, 32],
Technological accessibility	[3, 14, 26]
Legal, Ethical, and regulatory challenges	[3, 6, 14, 20, 21, 23–26, 32]
Consumer engagement hurdles	[3, 7, 16, 20, 26, 30]

In a systematic review, Riar et al. [16] drew up and presented a synopsis of the most recent research about AR shopping. The analysis uncovers a wide range of behavioral and psychological ramifications associated with the implementation of AR shopping. An in-depth review of the prominent technological features and theories of AR shopping. Moreover, Shen et al. [15] conducted a comprehensive analysis of the literature on Virtual commerce applications and identified the key elements that influence purchasing decisions and the design artefacts that are considered superior. Although a limited number of studies highlight possible challenges and address design issues related to AR/VR/MR shopping [7, 8, 20–22] or virtual commerce artifacts, none of these research focus primarily on metaverse application design issues and growing adoption factors for metaverse e-commerce, which are crucial for businesses to redesign their strategies and continue competitive.

The scope of our investigation is focused on the challenges that arise while creating metaverse e-commerce applications. Table 1 listed below presents the challenges associated with developing metaverse e-commerce applications in previous research. Table 1 illustrates that several previous studies have drawn attention to the significant concerns regarding privacy, security, and legal and ethical issues [23–25]. Data privacy in this new landscape is a constantly evolving objective. Another significant inquiry is how e-commerce enterprises operating inside the metaverse implement resilient security protocols. While protecting consumer privacy (i.e., data) and ensuring security (i.e., payment) turns into greater significance, metaverse e-commerce platforms should design their applications to protect user data, such as by protecting anonymous transactions, and secure data storage and data sharing

Table 2 Sub-themes, key themes, and related references

Key themes	Sub-themes	
Responsiveness system quality	Privacy Security Reliability (i.e., Trust, WoM, authenticity) Omnichannel marketing systems VR-based delivery tracking Blockchain-based arbitration	[3, 4, 6, 7, 9, 13, 21, 22, 26, 31, 32]
Perceived informativeness	Product informativeness Realistic product modeling Gamified experience	[15, 16, 21, 26, 33]
Perceived virtual marketplace	Virtual Retailing Virtual store/ mall design Virtual Product Quality Virtual Product Trial Contactless Payment Metaverse store design	[3, 5, 7–9, 13–16, 21, 26–29, 33]
Avatar influencer	Virtual avatar Virtual agents Virtual influencer advertising Virtual try-on campaign	[3, 4, 15, 21, 29–31]
Hedonic value	Entertainment value Emotional value Luxury consumption value Aesthetic value	[3, 6, 8, 9, 13, 21, 22, 24, 26, 27, 33]
Accessible metaverse infrastructure	AR device, VR device, 3D device, 3D scanner Decentralized blockchain technology Eye-tracking technology Meta-vertical technologies	[3, 6–9, 14, 16, 20, 22–24, 26, 27, 29, 32]
Digitalized consumer mindset	Digital consumerism Consumer e-shopping acceptance	[7, 14, 16, 21, 32]
Virtual consumer engagement	Virtual consumption experience Consumer virtual presence Virtual communities Metaverse purchasing experiences	[3, 7–9, 14, 20, 33]

policies. Furthermore, explores the evolving regulations that enforce the security of data, privacy, and virtual property rights, metaverse e-commerce needs to successfully navigate sophisticated legal landscapes to build trust in the virtual marketplace. More importantly, although the metaverse holds immense potential for revolutionizing the consumer experience, there are still several challenges to overcome, such as enhancing consumer engagement [3, 7, 16, 20, 26] and ensuring the availability of necessary infrastructure [3, 24, 26]. Therefore, many scholars have proposed the adoption of hedonic applications, specifically focusing on fun and pleasure [3, 15, 16, 21, 27, 28]. Particular challenges noticed in the development of metaverse e-commerce applications have been outlined in Table 1.

Answering RQ2: *What are the key drivers for consumer-centered adoption models?*

A summary of adoption factors (themes) among the retrieved publications is shown in Table 2. A total of 35 sub-themes and 8 key themes (factors) were identified. We have reviewed every factor used in the extracted study to identify the most prominent factors for extending metaverse e-commerce studies. Numerous research that makes utilize conventional IS frameworks, such as TAM [13], extended TAM [34], and unified theory of acceptance and use of technology-2 (UTAUT-2) [35], to investigate AR-based Virtual Try-on in shopping. Also, there have been numerous studies focusing on metaverse purchasing intent that have used conceptual models based on the extended IS model [8, 31]. Consequently, well-established IS factors are the prevailing and effective aspects that impact the adoption and acceptance of metaverse technology (i.e., AR/VR) in the context of virtual shopping. Nevertheless, these conventional adoption factors are limited in their ability to clarify the cognitive behavior of consumers while using cutting-edge technologies such as the metaverse. Although numerous IS factors found significant in prior literature in this area (i.e., [13, 15, 21, 22]), none have come up with a model as thorough as concurrent adopting metaverse e-commerce so far. Hence, examining the cognitive state of consumers during metaverse shopping remains particularly crucial. Therefore, this study has explored other unique factors (Table 2) that might contribute to the adoption of virtual technology, which strongly supports the effectiveness of metaverse adoption theories in the field of e-commerce.

Answering RQ3: *What might be a potential consumer-centered metaverse e-commerce adoption model from the IS perspective?*

Through the reflections from the literature review eight emerging factors were identified from thematic analysis. The research team then looked for expert feedback from IS researchers to get additional insight into the relationships among emerging metaverse e-commerce adoption factors. The conceptual model, derived from expert opinion and the review findings, is shown in Fig. 2. The experts' feedback highlighted several facets of the adoption of metaverse e-commerce that impact the re-design of e-commerce business processes. The investigation revealed many influential themes, including cognitive factors, technical challenges, a shortage of competing technologies, legal and ethical issues, and privacy and security concerns. This proposed conceptual model could potentially capture the significant implications for wider acceptance of the metaverse in e-commerce industries and society. However, while

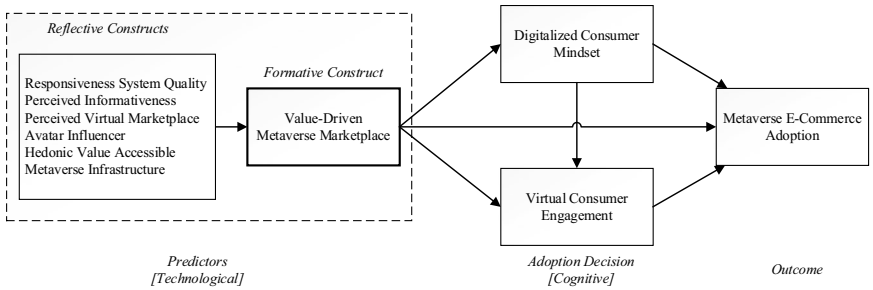

Fig. 2 Proposed conceptual model for metaverse e-commerce adoption

the application of metaverse in e-commerce industries is still in its infancy of development, it offers several prospects for future study involving interdisciplinary scholarly audiences.

4 Conclusion, and Future Research Avenue

This study aimed to demonstrate a comprehensive grasp of the key issues in metaverse e-commerce research and identify the factors that contribute to the adoption of metaverse e-commerce. Thus, the main focus of this study was to provide a comprehensive overview of the challenges at hand. Additionally, it attempted to identify the factors that contribute to adoption, making it possible to compare it with previous adoption strategies. We did not prioritize the short-term implementation of IS factors for serving the immediate needs of the metaverse e-commerce application. Our focus was on developing an evidence-based framework that utilizes a benchmark concept to strategically enhance the long-term viability of metaverse technology adoption.

This SLR extends the existing metaverse research by offering a comprehensive summary of previous studies focused on the adoption and application design of metaverse e-commerce. It also presents a framework for designing metaverse e-commerce applications on consumer behavior in virtual shopping. Comparing this thematic analysis to other review studies uncovered several interesting differences. Unlike prior research, this review study retrieved sample articles without any specific time restrictions. For instance, Riar et al. [16] restrict the time range of their study to articles from 2010 to March 2021. Second, the proposed conceptual model (Fig. 2) might greatly contribute to the significant difference between the current research and other existing studies. The research illustrates the practical ramifications for business organizations by emphasizing the evolving requirements of firms in the era of the metaverse, together with the associated challenges and consequences for e-commerce industries. Hence, the current study has established a solid groundwork for future exploration of the metaverse as an innovative business model. Following are some potential areas for further research:

Proposition 1: Measuring metaverse e-commerce adoption: Scale development and validation.

Due to the nascent state of metaverse e-commerce research, there is a lack of suitable measurement items to investigate the adoption strategy. The suitable scale is often a crucial determinant of the long-term sustainability and success of emerging technology. A reliable measurement scale ensures that the emerging technology (i.e., metaverse e-commerce) is capable of effectively managing the complex structure and needs of real-world applications. It comprises not only technological scalability but also scalability in terms of functionality, interoperability, accessibility, simplicity, and adaptability. After performing an extensive review of the existing research, identify the prospective items or questions that might be used to assess the construct. Subsequently, the measurement items may be verified by a three-step process: first scale validation through focus group discussions with end-users, followed by expert opinions. During the concluding phase, insights from several aspects may be integrated and a survey can be conducted to validate the results. The validation of the measuring scale goes beyond the traditional research conducted in the IS-based metaverse field. It also broadens the scope of the growing e-commerce industry and provides the first practical definition of the metaverse in e-commerce research. Additionally, the study sample can be collected within a cross-cultural context, which has the potential to provide valuable insights into border consumer perceptions, attitudes, and experiences.

Proposition 2: Examining technological and cognitive factors driving metaverse adoption in e-commerce.

Arguably it is expected that the metaverse will be the next major frontier for e-commerce, it is of the utmost importance to have a solid understanding of the technical and cognitive factors that will drive the adoption of the metaverse in c-commerce. Following the development of the measurement scale based on Proposition 1 a quantitative analysis may be carried out to figure out the key factors that promote the adoption of e-commerce. To circumvent the constraints of the methodological aspects, a mixed-method analytical approach may be used to better comprehend the crucial factors and their causal relationship. This approach includes PLS-SEM, CB-SEM, and fsQCA. This technique will make a valuable contribution to domains outside metaverse e-commerce. Furthermore, relevant stakeholders and legislative bodies may benefit from foundational knowledge of how the future of e-commerce can be leveraged through the value-driven metaverse marketplace in a digital society.

Proposition 3: Designing metaverse artifact toward digital-enabled e-commerce adoption.

Although IS scholars have acknowledged the importance of metaverse systems in implementing digital-enabled e-commerce, there is still a lack of appropriate understanding in designing such solutions. Prior studies have suggested several demands for metaverse e-commerce development, including the need to transform e-commerce

operations and address existing challenges by implementing suitable actions. This study recommends that IS research approaches may be used to address identified challenges (Table 1), hence providing valuable insights for future metaverse artifact design. By addressing the identified issues in metaverse e-commerce artifact design, a robust and sustainable platform for e-commerce ventures can be established in the long run. We propose that a user-centered artifact design approach can be instrumental in ensuring not only the integrity and excellence of the artifact itself, but also in guiding the design, execution, monitoring, and continuous development of the metaverse e-commerce platform.

5 Disclosure of Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Entertainment, Gaming Information Systems and Metaverse

Pankaj Bhambri and Sandeep Kautish

Abstract The chapter examines the profound influence of sophisticated information systems in the fields of entertainment and gaming, with a specific emphasis on the emerging idea of the metaverse. This virtual realm is defined by immersive and linked three-dimensional places. It utilizes advanced technologies like virtual reality (VR), augmented reality (AR), and blockchain to construct vast digital ecosystems. Within these environments, users may communicate, socialize, and participate in a wide range of activities. The chapter explores the structure and operation of these systems, highlighting their ability to improve user experience through the provision of smooth and highly interactive platforms. By incorporating AI-powered data analysis, these systems have the ability to customize user experiences, anticipate user preferences, and facilitate more immersive and dynamic interactions inside the metaverse. The chapter explores the social and cultural consequences of the metaverse within the realm of entertainment and games. This analysis explores the possibilities of innovative business models and sources of income, such as virtual real estate, digital assets, and in-game economies that are transforming conventional businesses. The chapter explores the difficulties and moral deliberations associated with privacy, security, and digital identity in virtual environments. This chapter offers a thorough analysis of the latest developments and upcoming trends in entertainment and gaming information systems. It serves as an essential resource for comprehending the changing landscape of these systems and their crucial role in defining the metaverse.

Keywords Virtual Reality (VR) · Augmented Reality (AR) · Blockchain · NFTs (Non-Fungible Tokens) · Artificial Intelligence (AI)

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1 Introduction

The introduction of the gaming metaverse, fueled by virtual reality (VR) technology, is generating significant excitement within the gaming industry that has become a prominent topic of discussion among gamers [10]. Recent polls indicate that over 52% of gamers in the United States hold the belief that the Metaverse has the potential to bring about a revolutionary transformation in the gaming industry. According to the most recent industry projections, the worldwide metaverse market is projected to grow from $100.27 bn in 2022 to $1,527.55 billion by 2029, with a compound annual growth rate (CAGR) of 47.6%. This increase in size adds to a significant rise in the acceptance of video gaming on the internet that relies on augmented reality/virtual reality patterns and technology [19]. VR-integrated gaming platforms utilize 3D imagery, VR headgear, expansive screens, and rooms equipped with sensory elements such as odors and tactile sensations to create a lifelike experience. The platforms have revolutionized the gaming business paradigm and significantly increased its popularity among gamers due to an exceptionally flawless and captivating virtual experience. The transformation of the game cyberspace into an engaging and interactive 3D platform through Metaverse gaming is captivating, as it provides immersive settings. This article provides a comprehensive overview of the gameplay metaverse and its impact on the virtual gameplay industry. It aims to equip you with the knowledge necessary to develop virtual gaming products for your business [39].

1.1 Overview of the Metaverse

The Metaverse is a virtual area that is collectively shared and generated by the merging of physically enhanced reality and virtual spaces that exist in a persistent manner. This includes all virtual realities, augmented reality, plus the Internet. This idea has become increasingly popular in recent years due to advancements in technology, namely in the fields of VR along with augmented reality (AR), which have made it possible to create more immersive experiences. The concept involves establishing a platform where individuals may engage with a computer-simulated setting and communicate with other users. The Metaverse holds the potential to fundamentally transform our interactions with the digital realm by erasing the boundaries that separate both virtual and physical realities [50]. The objective is to achieve a seamless incorporation of many technology components, such as VR, AR, artificial intelligence (AI), and social media, in order to establish a platform that serves not only for enjoyment but also for professional endeavors, education, and social interaction.

1.2 Significance of Entertainment and Gaming in the Metaverse

The metaverse along with the metaverse development solutions offered by a metaverse developing company have considerable potential to revolutionize the entertainment and media industries in the near future [16]. The integration of technologies such as virtual reality, blockchain technology, and AI will facilitate the emergence of novel modes of immersive storytelling, collaborative gaming, virtual actual events, and improved marketing techniques within virtual environments. As these technologies advance and change, we will encounter novel possibilities as well as obstacles in our experience and interaction with entertainment and media [27]. Following analysis provides an in-depth examination of the potential effects of the metaverse on the media and entertainment industry:

- Interactive Experiences and Immersive Storytelling: VR and AR will facilitate deeply engaging narratives and interactive encounters within the metaverse. Audiences will have the opportunity to immerse themselves in narratives from a first-person point of view and even have control over their progression. For instance, VR films with multi-episode VR series have the ability to immerse viewers immediately into intense scenarios and imaginative realms. Viewers have the ability to engage with the narrative, select several trajectories and viewpoints, and modify the final result. In the same vein, virtual theater along with live performances will increasingly offer a more engaging and participatory experience [7]. Global audiences have the opportunity to convene in a collective virtual environment to partake in the presentation. There is a potential for a certain degree of involvement and customization. The emergence of these novel types of immersive along with interactive storytelling will revolutionize our encounters and interactions with media and entertainment. The distinction between spectators and creators may become increasingly indistinct.
- Revolutionizing Esports and Gaming: The metaverse and its associated development services will transform the gaming industry through the provision of highly realistic virtual environments, characters, and interactions [3]. Players will get a complete sense of immersion and presence when playing games. Virtual reality applications will enable the emergence of novel game genres characterized by full immersion, lifelike simulations, and virtual presence. Players can engage in more organic interactions by utilizing their hands and physical movements. Cloud gaming will obviate the necessity of possessing costly gear. Players have the ability to play on any device, regardless of location. Massive online multiplayer games will provide the connection of a large number of people in virtual environments that they can share. Esports will experience increased popularity, immersion, and integration into the mainstream inside the metaverse. Enormous crowds will convene in virtual arenas to spectate elite players and gaming leagues engage in competition within their preferred virtual reality games. Players can engage in competitive gaming without the need to physically travel to certain locations [22]. The metaverse will significantly enhance the playing experience

and expedite the expansion of games as a media and arts sector through these means.

- Live Events and Virtual Concerts: Artists will have the capability to host complete virtual concerts, tours, and fan gatherings within the metaverse. Attendees from any location across the globe can participate and have the sensation of being in the front row. As an illustration, Travis Scott organized a concert inside the virtual world of Fortnite, which attracted an audience of more than 12 million viewers. Artists facing challenges in touring worldwide will now have the opportunity to connect with their international fan base. Likewise, significant live events such as award shows, conferences, and sports will take place in virtual arenas [32]. These virtual environments allow large worldwide audiences to come together and participate in events, creating a feeling of shared presence, regardless of their physical location. The live events plus music touring sectors will generate additional sources of income through virtual products and exclusive internet content. The metaverse provides a novel platform for these businesses to engage with a larger audience through innovative methods.
- Enhanced Marketing and Advertizing Strategies: Brands will have the capability to develop exceptionally captivating virtual advertisements, stores, and encounters within the metaverse. They have the ability to advertise their items using innovative methods that engage and captivate the audience. Brands can utilize various strategies such as virtual showrooms, interacting billboards, customized avatars/clothing, within the game placement of goods, and sponsored online events [40]. Nike purchased a virtual footwear company in order to market exclusive and valuable virtual sneakers, demonstrating the possibilities of virtual products and trade. Brands will collaborate closely alongside influencers who endorse products via their digital media streams, and encounters in the metaverse. Influencers have the opportunity to engage in partnerships with brands for the purpose of promoting products, sponsoring their online events, and creating unique virtual content [44]. These novel advertising and marketing methods will enable brands to connect with people in intimate and genuine ways through virtual encounters. Collaborations with influential individuals and content creators in the virtual reality world will become increasingly prevalent and influential.

2 Evolution of Gaming and Entertainment Systems

The video gaming market is projected to exceed two hundred billion USD in the year 2023. Mobile games account for the majority of market income, while console games contribute to nearly one-third of the revenue. By 2025, the mobile gaming industry is projected to surpass 11.35 billion USD, even within the United States alone [15]. Video games have significantly integrated into the lives of numerous individuals. The development of gaming has been a captivating occurrence in human history. There is a wide variety of genres that cater to diverse interests, and you have the option to play on your television, smartphone, or tablet. You have the option to engage in online or

offline gameplay, either individually or in the company of companions. Alternatively, you may choose to spectate others' gameplay in real-time [28]. The misconception that only young male teenagers engage in gaming has long been disproven. In fact, 38% of those who play video games in the United States fall within the age range of 18–34, while 7% are aged 65 and over. Regarding gender, 46% of players in the United States are female [1].

2.1 Transition from Traditional to Digital Systems

The 1990s witnessed a period of swift technical improvement, marked by notable progress in graphics as well as gameplay dynamics. The period of 16-bit systems exhibited notable 2D games like Super Mario World along with the Legend of Zelda: A Link Journey Past, which established fresh benchmarks for gameplay along with storytelling inside the realm of two dimensions [14]. As the decade advanced and 32/64-bit consoles appeared, Nintendo, Sega, with Sony engaged in intense competition. During this era, notable games like as Doom, a Street Fighter II, as well as Pokemon were released, which not only shaped their respective genres but also appealed to a broader range of players, thus extending the gaming industry. The 1990s witnessed the advent of 3D playing games, a transformative development that revolutionized the design and gameplay of video games [33]. Games such as Super Mario 64 as well as The Legend of Zelda: Ocarina of Time was innovative in their use of three-dimensional graphics and gameplay mechanics, which greatly enhanced the player's immersion and allowed for seamless movement within the game environment. The advent of the new millennium marked the onset of a prosperous era in the gaming industry, characterized by notable advancements in online collaborative experiences and the ongoing expansion of the PC gaming landscape. During this era, video games such as World of Warcraft, Halo, as well as The Sims were extremely popular and demonstrated the immense possibilities of video games as a means of entertainment as well as social engagement [47]. During this age, there was a significant increase in the popularity of mobile gaming, which made interactive entertainment accessible to a wider and more varied group of people than ever before. The 2010s were characterized by the emergence of autonomous game creators and the growing assimilation of gaming into popular culture. Indie games such as Minecraft, Undertale, and Celeste provided distinctive experiences that questioned conventional standards and showcased the ingenuity and variety within the gaming industry [6]. During this decade, gaming experienced a significant growth in its presence across many platforms, such as smartphones and tablets, hence increasing its accessibility to a broader range of users. In the 2020s, we are observing the ongoing advancement of game technology, characterized by the emergence of virtual reality and augmented reality, which provide novel and immersive experiences. Games such as Half-Life: Alyx and Pokémon GO are leading the way in this innovation, pushing the limits of what gaming can achieve. Advancements in machine learning and artificial intelligence are defining personalized and dynamic video game experiences in this decade

[17]. Additionally, innovations in cloud computing along with high-speed internet are making gaming experiences more fluid and accessible, independent of hardware restrictions.

Developers are increasingly recognizing the significance of inclusivity by portraying a diverse range of origins, identities, & life experiences. The adoption of inclusion not only enhances the enjoyment of gaming for a broader range of players but also mirrors the various composition of the worldwide player population. Games such as The Last of Us Part II and Horizon Zero Dawn are praised for their well-developed and complex characters from diverse backgrounds, reflecting a rising inclination towards more inclusive narrative [23]. In addition to their entertainment value, video games are becoming more recognized for their promise in the realms of education, rehabilitation, and skill enhancement. Education-focused games such as Prodigy Math Game along with Minecraft: Education Edition are progressively advancing, providing immersive learning opportunities that can enhance conventional teaching approaches. Therapeutic games, like SPARX, specifically created to aid young folks with depression, plus SuperBetter, which enhances personal resilience, are now being used in mental health therapy to provide novel avenues for individuals to interact with therapeutic material. Games are utilized to improve cognitive ability, problem-solving skills, and physical coordination, hence facilitating skill development [30].

The progression of games is a continuous exploration of human ingenuity and technology advancement. Video games have evolved from their niche origins to become a prominent and essential component of our worldwide cultural landscape. They have surpassed the boundaries of recreation, learning, and social interaction [36]. The rapid progression of technology opens up boundless possibilities for innovation and cultural influence in the gaming industry. The future is a realm of possibilities that can only be speculated upon.

3 The Metaverse: Definition and Key Concepts

The metaverse is an ambiguously defined concept that encompasses virtual environments where users, represented by avatars, engage in interactions, typically in three-dimensional formats, with a primary emphasis on economic and social connectivity [43]. The phrase metaverse was first coined in the 1992 fantasy novel Snow Crash, where it was created by combining the words “meta” and “universe”. Snow Crash portrays the metaverse as a theoretical version of the Internet that functions as a unified and immersive virtual world, made possible by the utilization of VR and AR headgear. The phrase “metaverse” is commonly associated with virtual reality technology, particularly in the context of Web3, which emerged in the early 2020s. Companies have used the term as a buzzword to overstate the advancement of certain technologies and initiatives for the purpose of public relations. Concerns around information privacy, consumer addiction, and user safety arise in the metaverse due to issues faced by the social media and video gaming industry as a whole.

Elements of technology from the metaverse have previously been created and implemented in internet-based video games [49]. The virtual world platforms Second Life, established in 2003, is commonly referred to as the inaugural metaverse due to its integration of social media features within a persistent three-dimensional environment where users are represented by avatars. However, claims of the creation of the metaverse emerged shortly after the term was coined. Initial endeavors encompassed Active Worlds including The Palace.

Notable games that are considered part of the metaverse includes Minecraft, Habbo Hotel, VRChat, World of Warcraft, Fortnite, and the game development platform Roblox. During a January 2022 conversation with Wired, Philip Rosedale, the inventor of Second Life, defined metaverses as a virtual reality space that resembles the Internet but exists in three dimensions and is inhabited by real individuals [4]. Massively interactive online games frequently incorporate social interaction and 3D virtual worlds as essential components. Microsoft purchased the VR business AltspaceVR in 2017. Since then, Microsoft has integrated virtual avatars and virtual reality meetings into Microsoft Teams. Facebook introduced a VR platform named Facebook Horizon in 2019. In 2021, the company underwent a name change to "Meta Platforms" and its chairman, Mark, Several virtual reality technologies promoted by Meta Platforms are still in the process of being developed. Frances Haugen, a whistleblower from Facebook, expressed disapproval of the decision, stating that Meta Platforms' persistent emphasis on projects aimed at increasing growth is mostly at the expense of maintaining safety on its networks [12]. The Meta Platforms company has also encountered user safety scrutiny in relation to Horizon Worlds, primarily owing to instances of sexual harassment taking place on the platform. Meta incurred a substantial loss of more than $10 billion in 2021 due to its metaverse development division. Mark Zuckerberg anticipates a significant rise in operating losses for the year 2022. Certain metaverse implementations depend on digital currencies, frequently in the form of cryptocurrency. Assets in the metaverse are occasionally exchanged as non-fungible tokens (NFTs) and utilize blockchain technology to record ownership. Potential uses for metaverse technology encompass enhancing work efficiency, interactive educational settings, online commerce, large-scale audience engagement, healthcare, and real estate [21].

3.1 The Role of Blockchain and NFTs in the Metaverse

NFTs have garnered considerable interest in recent years, particularly in relation to their function inside the metaverse. NFTs are distinct and indivisible digital possessions that are well-suited for reflecting ownership of virtual products and antiques in the metaverse. The growing acceptance with the metaverse has led to a need for the development of NFTs, as they offer a means to verify and exchange digital assets in a safe and transparent fashion. The value of a digital asset is determined by several factors, including its rarity, uniqueness, the standing and popularity of its creator, the need for that specific form of NFT, the lack of similar items, and the overall worth

along with attractiveness of the virtual item [13]. Any variation in these characteristics can directly affect the perceived worth of an NFT within the metaverse, hence altering its purchase and sale price. NFTs as well as blockchain technology are essential for the creation and operation of the metaverse. Blockchain technology functions as the foundational framework that enables the decentralized structure of the metaverse, guaranteeing the safety, openness, and unchangeability of digital assets along with transactions inside the virtual realm. The metaverse ecosystem is safeguarded by blockchain technology, which use decentralized consensus systems to authenticate and document transactions [26]. This makes it highly challenging for malicious individuals to tamper with or counterfeit digital assets. Through the utilization of cryptographic methods, blockchain guarantees the safety and consistency of your digital possessions in the metaverse, rendering it quite difficult for them to be altered or pilfered. The utilization of blockchain technology has significantly influenced the advancement of the metaverse by establishing a dependable and transparent structure for generating, possessing, and exchanging digital assets. Blockchain guarantees the origin and genuineness of your digital possessions by permanently documenting each transaction on the decentralised ledger. The advent of blockchain technology has presented unparalleled prospects for creators, buyers, and investors to engage in the metaverse with assurance, since their assets are safeguarded by robust cryptographic security mechanisms and the decentralized structure of blockchain [35].

4 Integration of Entertainment and Gaming in the Metaverse

The metaverse is a fully immersive virtual realm that operates through the utilization of AR, VR, and AI. It has the potential to fundamentally change the way we acquire and engage with media. It is not solely about seeking refuge in a virtual realm and surpassing limits; it also involves utilizing novel opportunities for narrative [41]. This technology facilitates the development of more profound audience involvement and generates wholly novel types of amusement. Here are some of the numerous benefits of incorporating the metaverse within the realm of media and entertainment.

- Immersive Storytelling: The metaverse extends much beyond the mere act of passively consuming media. Envision immersing yourself in a historical era by physically traversing a meticulously reconstructed urban environment or experiencing the sentiments of a fictional persona by embodying their virtual avatar [11]. Such a high level of immersion has the ability to create stronger bonds with storylines and have long-lasting impacts on viewers. This form of immersive seeing is also highly efficient in the field of education.
- Global Reach: Physical obstacles disintegrate within the metaverse. Artists have the ability to establish connections with fans from all around the world, eliminating any geographical constraints. With the assistance of VR and AR technologies, you

may directly experience an actual concert in Paris from the comfort of the living room in Tokyo [31].

- Personalized Experiences: The metaverse enables the customization of material to suit individual preferences, maximizing the utilization of artificial intelligence and the analysis of vast quantities of data. For this purpose, every prominent firm is collaborating with a top-tier artificial intelligence technology company to incorporate the capabilities of AI into its metaverse platforms [18].
- New Revenue Streams: The metaverse presents vast opportunities for creative monetization strategies. Creators have the ability to sell virtual goods, provide unique experiences within their virtual environments, and establish economic systems within their online worlds. The metaverse is revolutionizing both entertainment and the incentives for content providers by merging both the digital and physical realms [29].

5 Development and Design of Metaverse Games and Entertainment Systems

Metaverse gaming encompasses the integration of virtual reality, mixed reality, and internet group games. Consequently, it generates vast virtual realms where individuals may interact, form friendships, and engage in various activities. The pace of technological advancements is rapidly transforming several aspects, particularly in the domains of image creation, network construction, and computational capabilities [20]. The growth of metaverse game realms has been facilitated by this. Metaverse gaming development firms are leading the way in online amusement with this innovative gaming technology, attracting attention and investment. The expansion of metaverse game worlds can be attributed to the rapid advancements in technology, particularly in the fields of visual effects, computer networks, and processing capabilities. With the help of advanced technology and software, it is now feasible to create engaging and exceptional experiences. The widespread availability of high-speed connectivity has made it effortless for metaverse game environments to facilitate global connections among individuals. In addition, this connectedness fosters communal experiences, enabling users to collaborate, engage in combat, or simply socialize within these digital realms [34]. The realization of a massive digital realm accessible to everybody was once but a fantasy, but now it has become a tangible prospect. Metaverse game realms offer more than mere gameplay. Significant emphasis is placed on acquainting oneself with others and constructing communities. Users can engage in interpersonal communication, establish connections, and cultivate friendships by employing methods that closely resemble the way individuals interact face-to-face. The combination of games and interactions with others has garnered significant popularity among a diverse variety of gamers. Both metaverse gaming production businesses and players have the potential to generate income within metaverse game environments. These locations facilitate the creation, sale, and exchange of virtual products and currency. Due to many factors, such as marketing

and trade, an increasing number of real-world organizations and entrepreneurs are interested in investing in or utilizing the metaverse. Metaverse games offer a departure from conventional video games by allowing players to exercise autonomy in determining their gameplay strategies, in contrast to the predetermined objectives and narratives found in traditional games. Consequently, whenever a user accesses the Metaverse, their experience is distinct and tailored to their preferences [48]. The ability to customize and modify game realms is a significant aspect of metaverse games, since it empowers players to exercise control and unleash their creativity. Metaverse games generate intricate and immersive virtual environments that surpass conventional games. These spaces serve as venues for virtual music performances, business negotiations, art exhibitions, and educational gatherings. They may either remain consistent or undergo modifications throughout time. The Metaverse has expanded beyond its original confines within video games and has transformed into a dynamic and ever-changing digital realm.

A game creation company specializing in the Metaverse is playing a pivotal role in the transformation of Metaverse gaming. These enterprises utilize contemporary technologies to generate intricate and dynamic virtual realms that captivate players. These firms provide a diverse array of services that bring the Metaverse into existence, encompassing activities such as designing, writing, creating virtual assets, and establishing networks. Metaverse game development businesses possess exceptional expertise in crafting visually stunning and seamlessly immersive game environments. They utilize state-of-the-art imagery and design software to construct virtual realms that closely resemble reality and dreams, providing players with an unparalleled gaming experience [2]. A significant number of Metaverse games employ blockchain technology to ensure the security, transparency, and legitimate ownership of in-game goods. A Metaverse game creation service specializes in integrating blockchain solutions that enable players to have true ownership and the ability to trade virtual assets within the gaming environment. In order to maximize accessibility, Metaverse offers a wide range of game creation options that cater to various platforms, including computers, PCs, and mobile phones. This ensures seamless device switching for players, allowing them to enjoy a consistent and enjoyable gaming experience. Artificial intelligence is crucial for enhancing gameplay in the Metaverse. Game companies utilize AI algorithms to develop intelligent non-player characters (NPCs), dynamic environments, and interactive narratives that adapt to player choices. This results in a distinctive and always changing game encounter.

6 Challenges and Opportunities

In order for the metaverse to fully achieve its promise, it is imperative to address and overcome the numerous risks and problems it provides.

- Technical Hurdles: Achieving a completely immersive and flawless metaverse experience will necessitate overcoming substantial technical obstacles. These factors can encompass latency, subpar graphics, and cumbersome user interfaces that impede the acceptance of a product if not executed properly [9]. Significant investments in research and development (R&D) will be necessary to provide the sophisticated software, hardware, networking, along with rendering capabilities that are essential.
- Privacy and Security Concerns: With the increasing amount of time people spend in online environments, there are legitimate concerns around the acquisition, protection, and utilization of personal data in terms of privacy and security. In the absence of adequate precautions, unauthorized individuals may gain access to confidential data, engage in identity theft, and monitor sensitive discussions [38]. Robust encryption, stringent access restrictions, and adherence to data protection standards will be of utmost importance.
- Mental Health Impact: This could potentially have adverse effects on the user's mental well-being, manifesting as addiction, social isolation, and detachment from reality [36]. To ensure that certain users are able to sustain healthy relationships and fulfill their duties outside of the metaverse, it is necessary to employ mindful usage and establish realistic boundaries. Additional investigation is necessary to examine the enduring psychological consequences.
- Economic Impacts: The metaverse possesses significant economic potential and exerts a substantial influence on a wide array of sectors. The majority of analysts forecast an exponential industry expansion, projecting that revenues generated from metaverse technology will surpass $800 billion by 2024. As the metaverse evolves and reaches a more advanced stage, it will emerge as a significant driver of new business models, sources of revenue, and job opportunities, contributing significantly to the GDP and overall productivity [30]. A variety of innovative income models are being developed, such as digital goods/assets, virtual real estate, experiential services, and others. As an illustration, corporations have the ability to establish virtual stores, music venues can offer virtual tickets for sale, and game makers can facilitate in-app purchases. Individuals can also create revenue by monetizing their specialized talents, services, including digital creations. Economists estimate that the metaverse holds the potential to augment global GDP by as much as $3 trillion annually as its adoption rate rises [45]. Over the next decade, it is anticipated that more than 10 million employment would be generated specifically in the field of technology development, platforms, experiences, hardware, and infrastructure. The metaverse will require a greater number of professionals in fields such as programming, design, architecture, advertising, and creative roles.\n\nThe metaverse has the potential to generate a significant economic upturn by enabling the exploration of fresh avenues for expansion and enhancing operational effectiveness. Businesses can utilize it to gain access to untapped international clients and marketplaces at a reduced expense [25]. Furthermore, it enables the emergence of novel business models and sources of income that are unattainable in the realm of physical existence. In summary, provided that the technological and adoption obstacles can

be successfully addressed, the metaverse promises a promising and novel digital frontier for economic growth.

- Regulation and Governance: The advent of the metaverse gives rise to significant inquiries on regulation and governance. With the expansion of the metaverse, it is probable that there will be a rising demand for governmental supervision and control. The initial crucial aspect is to the moderation of content and ensuring the safety of users. The metaverse introduces novel dimensions in virtual realms, enabling users to engage in unprecedented forms of interaction. This creates opportunities for potential issues related to harassment, bullying, and the dissemination of unlawful or hazardous material [8]. Platforms must devise strategies to regulate content and conduct in these novel ecosystems. Authorities should contemplate implementing regulations pertaining to the safety and welfare of metaverse users. Another factor to consider is the capacity of different systems or software to work together and the ease of transferring data between them [17]. At this stage, it is obvious that the metaverse is highly fragmented, characterized by numerous enclosed ecosystems created by major technology corporations. In order for the metaverse to truly thrive, numerous experts think that the establishment of interoperability standards is crucial. These standards would enable avatars, digital assets, and user data to effortlessly transition between different platforms. Developing open metaverse standards may necessitate coordination between enterprises or government regulatory frameworks. An additional crucial aspect of governance involves the laws governing of virtual currency and assets. Cryptocurrencies and NFTs are likely to play a significant part in the economics of the metaverse [47]. However, at present, there is a lack of clear regulations regarding the appropriate treatment and regulation of these entities. As the utilization of digital assets increases, governments will have the task of formulating well-considered policies and regulations. In order to fully achieve the potential of the metaverse and ensure user safety, it is necessary to have proactive governance and open discussions including legislators, companies, specialists, and the general public [37]. The metaverse is an emerging domain that holds great promise but also presents numerous unresolved issues about assets, safety, interoperability, and other aspects. It will be necessary to create appropriate governance approaches.
- User Adoption Predictions: The metaverse is now in its early stages of development, and it will take several more years for it to be widely adopted by the general public. The perceptions of present consumers vary, with some individuals expressing enthusiasm about the potential opportunities, while others harbor skepticism and uncertainty on the advantages. Various factors will dictate the speed at which the metaverse becomes widely adopted.
- Current Consumer Perceptions and Readiness: The majority of customers have limited knowledge about the metaverse and its potential benefits. Surveys indicate that the level of knowledge of the metaverse has significantly increased in 2022; yet, it still stands at less than 50% on a global scale. Early adopters primarily consist of technology aficionados and gamers. The majority of customers will probably need additional marketing efforts and practical demonstrations before they completely adopt the metaverse. Consumer preparedness also encompasses

issues around privacy and security [5]. Prior to fully engaging with the metaverse, the majority of consumers desire reassurance regarding the robust protection of their data and virtual identities. Some users are hindered by motion sickness and the unintuitive controls of VR. The overall preparedness will enhance as the technology progresses and becomes more user-friendly.

7 Future Directions and Emerging Trends in India

The metaverse improvements are driven by five essential content, vectors: hardware, infrastructure, community, and currency. International organizations in the technology and communication sector have begun creating rules to ensure standards are upheld for the wide range of technologies required by the metaverse [46]. The blockchain will be the pivotal technology for the widespread adoption of the metaverse. The International Telecommunication Union (ITU) released the inaugural set of global standards for blockchain technology in 2019. In 2020, the Institute of Electrical and Electronics Engineers (IEEE) published the IEEE standards for Data Format for Blockchain Systems to ensure consistency [42]. Meanwhile, individual nations are likewise endeavoring to formulate policies about the metaverse and its associated technology. For example, the South Korean government is one of the early investors in the metaverse, allocating a substantial amount of US$ 177.1 million to support the emerging metaverse business in the country. Countries such as the United States (US), China, Japan, and the UAE have established legislation around cryptocurrency trading and the utilization of blockchain technology for digital money. India has initiated the process of developing the National Strategy on Blockchain, marking the initial stage towards that goal [14]. India is now implementing the 5G testbed, developing the Central Bank Digital Currency (CBDC), and conducting trials of quantum communication technology.

The utilization of metaverse encompasses the development of intelligent urban areas, entertainment, gaming, telecommuting, education, tourism, and social networking. The convergence of the COVID-19 pandemic, widespread internet and smartphone usage, advancements in blockchain technology, and the emergence of Web 3.0 have all facilitated the development of the metaverse. While numerous technological businesses are venturing into other endeavors, gaming is widely regarded as the gateway to the metaverse realm [24]. Brands are leveraging the opportunities offered by games to interact with in-game environments in order to expand their audience and get visibility through metaverse stores and NFTs. Various sectors, including music, fashion, cosmetics, sports, and education, are already collaborating with gaming companies to integrate their branding into the gameplay [44]. Additional sectors, including transportation, defense, and smart cities, are rapidly entering the metaverse realm. A multinational consultancy firm, Ipsos, conducted a survey in 29 countries which revealed that in India, over 70% of adults believe that the development of metaverse applications such as virtual learning, entertainment, gaming, socialization, and tourism will significantly impact people's lives in the next decade.

The emergence of the metaverse will give rise to new business methods, innovative content, and fresh concepts for interaction that will appeal to both gamers and non-gamers. India's gaming sector is expanding, with a significant share being occupied by mobile and computer video games. In 2020, the country recorded a total of 450 million users, ranking second globally after China. The young demographic in India, which accounts for 46% of the population, plays a vital role in the user base [19]. The gaming business experienced significant growth due to the pandemic-induced lockdowns and the widespread availability of internet connectivity. Based on the 2021 data, the Indian gaming business is predominantly focused on mobile gaming, which holds a share of over 90%. PC gaming accounts for 9%, while console gaming represents 4% [10]. The majority of users in India are casual gamers who engage in games that do not necessitate expertise and offer minimal monetary incentives, if any. In 2021, the mobile-based casual gaming market generated approximately US$0.7 billion, while the e-sports sector made US$26 million. In order to achieve comprehensive growth of the metaverse industry in India, it is imperative that both the casual and e-sports sectors see expansion. Hardcore games, like e-sports, offer a platform for the virtual world to present game-related content in a more universal manner, akin to the real world. This aligns with the goals of the metaverse. Online games like Minecraft empower players to construct a virtual realm [40]. In India, this has led to the emergence of a Minecraft content-creating community that broadcasts its virtual world on YouTube and earns money from it. This enables the content creator to produce diverse content for sharing and utilize it for streaming or commercializing as an NFT. The Indian gaming and animation industry has initiated the process of creating material that is distinctively Indian. Loka is a start-up established in New Delhi that is the first multiplayer gamified virtual metaverse in the country. It has generated a three-dimensional representation of actual urban areas and geographic locations. OneRare, a start-up, released its inaugural play-to-earn food metaverse game in March 2021. The emergence of the metaverse will present a novel issue for Intellectual Property (IP) rights. Ownership of art and properties in the physical world is distinct from that in the virtual realm, and it is crucial to safeguard this distinction in order to foster growth and success in the Animation, Visual Effects, Gaming, and Comics (AVGC) industries [3]. NFTs might give rise to legal issues pertaining to the ownership and rights of intellectual property. To prevent intellectual property theft, it is crucial to conduct thorough research and analysis of the conditions and smart contract associated with the NFT transaction. India lacks the necessary resources and capabilities to effectively address the challenges associated with metaverse technology, particularly in terms of safeguarding privacy. The notice and consent procedure outlined in the draft Data Protection Bill (DPB) may be inefficient due to users frequently transitioning between several virtual environments, making obtaining user consent burdensome. Hence, it is imperative to ensure that the DPB is future-proofed in order to align it with the requirements of the metaverse [27]. It is important to strike a balance between exchanging data with trust and processing data within a country's territorial bounds. Restrictions on data exchange and processing can impede the advancement of the metaverse and could impede the progress of the technology. Homomorphic encryption, which involves transforming

data into cipher text, enables the secure sharing of data across boundaries, minimizing the risk of unauthorized access or misuse [39]. It is necessary to implement intellectual property regulations, incorporating elements of the metaverse, in order to combat content piracy. Platforms can mitigate privacy concerns by including techniques such as disguising, invisibility, and mannequin. These technologies allow users to choose alternative avatars, become undetectable, or substitute their avatar with a bot, thus evading tracking.

8 Conclusion

One of the major hurdles faced by the Indian metaverse for gaming business is the scarcity of personnel and expertise needed for chip manufacturing and audio-visual game content development. India is making efforts to narrow the gap and offer training to acquire the necessary skills to succeed in the area through the newly established National Semiconductor Mission and AVGC task force. The potentialities presented by the metaverse are boundless. In order to facilitate the early adoption of the metaverse, it is crucial for the Indian gaming sector and government rules to be aligned [15]. While the Metaverse may require some time to fully realize its potential, if achieved, it has the ability to generate a plethora of new economic prospects. India, with its growing technical dominance and population advantage, has a unique opportunity to fully capitalize on the potential of the metaverse.

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Enhancing Healthcare Delivery with Blockchain and Metaverse Synergy

Rihab Benaich, Saida El Mendili, and Youssef Gahi

Abstract Healthcare, a crucial societal domain, is pivotal in improving health and increasing life expectancy. However, it grapples with challenges such as high costs, unequal access in different communities, and concerns about protecting data privacy and security. Traditional healthcare systems often require assistance to handle the changing needs of the industry. This is where new technologies step in. The metaverse, a virtual world, offers possibilities for remote consultations, virtual training, and rehabilitation services. Similarly, blockchain technology, with its secure and transparent data storage capabilities, can help address issues related to data security in healthcare. This paper thoroughly examines how the intersection of the metaverse and blockchain can enhance healthcare services. We delve into the opportunities they bring, the obstacles they encounter, and the potential future advancements that could revolutionize the field, such as AI-powered virtual doctors and decentralized health records.

Keywords Metaverse · Blockchain · Healthcare · Smart contracts · NFTs · VR

1 Introduction

A robust healthcare system is not just a cornerstone of a thriving society but a necessity we cannot overlook. It detects health issues early and provides effective treatments similar to regular maintenance that keep a car running smoothly. Our bodies, too, benefit from consistent healthcare, including visits to doctors and

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dentists, adopting healthy lifestyle habits, and managing chronic conditions effectively. However, ensuring access to these services is not just a challenge but a pressing issue that demands immediate attention. The escalating healthcare costs can burden individuals, forcing them to choose between necessary medical care and basic needs like housing or food. This financial pressure disproportionately affects low-income groups and communities, exacerbating existing health inequalities. Moreover, accessibility is further complicated by geographical limitations, where people in certain areas may struggle to reach specialists or advanced medical facilities, leading to an unequal distribution of healthcare resources. We must address these challenges promptly and effectively, and this research aims to contribute to that urgent need.

Despite being crucial for record-keeping purposes, traditional medical information systems can hinder healthcare delivery due to data fragmentation issues (Fig. 1). Patient data is often scattered across systems, making it difficult for doctors to overview patients' medical histories. An example is when a doctor has to gather pieces of a patient's history from software platforms. Important information, such as allergies or past medication reactions, could be dispersed across systems, causing delays in diagnosis, higher risks of medication mistakes, and missed chances for care.

Moreover, some traditional systems are known for their obsolete interfaces. Focusing on well-being, healthcare providers might find themselves necessitating help with complex software that requires excessive time and effort to navigate. For instance, a doctor grapples with an interface rather than interacting with the patient. This frustration not only affects productivity but also diminishes the quality of patient engagement. Another challenge comes from interoperability issues; when systems need help communicating with each other, sharing data smoothly between healthcare facilities becomes problematic. Medical records might be incompatible with the existing system when a patient requires treatment at another clinic. This need for interoperability hinders collaboration among healthcare professionals, making it hard to create care plans tailored to the patient's requirements. Moreover, traditional systems might not employ robust encryption methods, leaving them vulnerable to

Fig. 1 The primary challenges of traditional healthcare information systems

cyber threats like hacking and malware. Additionally, updating storage devices or access restrictions can raise the chances of data being compromised or stolen. These security weaknesses not only put confidentiality at risk but also disrupt the provision of healthcare services by obstructing the retrieval of vital medical data, which could lead to delays in diagnosis and treatment. Furthermore, establishing and maintaining these systems from the start can be expensive for healthcare institutions. Moreover, expanding these systems to handle increasing data amounts or adding features can pose challenges requiring many resources. Also, maintaining data accuracy and uniformity among these systems can be challenging, potentially causing problems in coordinating care and making essential decisions.

The existing literature has played an essential role in bringing attention to the limitations of healthcare information systems. Extensive studies have detailed the healthcare system's numerous challenges, from data spread across platforms to user interfaces and a lack of interoperability that hampers collaboration. These obstacles result in a healthcare domain requiring help to offer a comprehensive view of a patient's history, potentially causing delays in diagnoses, medication errors, and missed opportunities for preventive care. While efforts have been made to tackle these issues, the persistence of these challenges underlines the urgent need to incorporate advanced technologies into healthcare practices.

Hence, the metaverse, a world designed for real-time interactions, offers a compelling glance into a future full of possibilities. In a scenario where doctors can enhance their skills through simulations of medical procedures, patients can receive specialized care from specialists far away through virtual consultations. On the other hand, blockchain technology, with its decentralized ledger system, presents a promising solution. By creating a secure record of a patient's data, blockchain ensures authorized access for healthcare providers across various institutions, eliminating interoperability issues that often hinder collaboration and impede the development of cohesive care plans. By tackling the metaverse and blockchain technology capabilities, we can envision a future healthcare system that integrates information systems and inherently focuses on patient needs. The merging of these technologies could transform how healthcare is provided, bringing about an era of connectivity, privacy, and ultimately enhanced patient care.

The remainder of this paper is organized as follows: Sect. 2 presents the relevant studies done in the healthcare industry using blockchain and metaverse and their combination. Sections 3 and 4 review the fundamentals of blockchain and metaverse. Section 5 highlights the key benefits of Blockchain and metaverse in healthcare. Section 6 analyzes and discusses the challenges of traditional healthcare information systems, showcases the benefits of blockchain and metaverse intersection in healthcare, and discusses their challenges. Section 7 concludes the paper with a summary and finishes with some future works.

2 Related Works

Recently, much focus has been on how combining blockchain technology and the metaverse can impact healthcare. Many studies are examining how these technologies can help solve the challenges faced by healthcare systems, such as issues with data security, accessibility, engaging patients and improving efficiency. This section explores how different research studies have used blockchain and the metaverse to innovate and enhance healthcare delivery systems (Table 1). Research on blockchain in healthcare mainly examines its potential to revolutionize how data is managed and processed [1]. The secure and decentralized nature of blockchain ensures that medical records remain safe, transparent and unchangeable without agreement from all parties involved. Studies have shown how this technology can improve data security and patient confidentiality, which are often at risk in healthcare systems due to centralized data storage methods [2, 3]. For instance, some research illustrated the use of blockchain to develop electronic health records systems that facilitate secure data sharing among authorized individuals, reducing the chances of breaches or unauthorized access [4]. In healthcare research involving the metaverse, there is an exploration into how it can revolutionize care using technologies. Studies have explored virtual reality environments for therapy sessions, surgical training programs, and patient education.

The metaverse offers interaction and engagement that traditional healthcare systems often lack, especially in remote or underserved areas [5]. Recent research has started to delve into the combined use of blockchain technology and the metaverse. These studies seek to utilize blockchain security and transparency to protect the metaverse's data environments. For instance, incorporating blockchain into VR healthcare apps can ensure that all patient interactions and data within the metaverse are securely recorded. This integration can significantly boost trust in healthcare platforms by guaranteeing data accuracy and adherence to privacy laws.

Moreover, these technologies help tackle inefficiencies in healthcare management. Smart contracts, an element of technology, can automate administrative tasks like claims processing, consent handling and compliance monitoring within metaverse platforms [6]. This automation simplifies processes, reduces expenses, and enhances efficiency in the healthcare system.

The combination of blockchain and the metaverse in healthcare has shown promising outcomes. However, the existing studies focusing on using these technologies together still need to be expanded early. Moreover, these studies mostly look into blockchain or the metaverse separately, examining their effects on privacy, data security, and enhancing patient care experiences. However, studies explore how working jointly with both technologies could improve healthcare practices. This research gap points to an opportunity for investigation. More in-depth studies are needed to understand the combined potential of blockchain and the metaverse. These studies could explore how blockchain-secure data management can enhance experiences in the metaverse, revolutionizing areas like remote surgeries, patient data handling, and real-time health monitoring.

Table 1 Contributions done using blockchain and metaverse for healthcare purposes

Adopted technology	Paper	Year	In the healthcare domain?	Contribution
Blockchain	[7]	2024	Yes	The authors presented the "Pattern Proof Malware Validation" (PoPMV) algorithm designed for blockchain in industrial cyber-physical systems (ICPS). This innovative algorithm utilizes a deep learning model (LSTM) and reinforcement learning techniques to boost security in ICPS-enabled healthcare applications. Its goal is to address vulnerabilities, enhance processing speeds, detect unknown cyberattacks, and improve the functionality of ICPS
	[8]	2024	Yes	The authors introduced an encrypted K-based clustering-based K-means clustering-based consensus protocol (EKMC SCP) tailored for the Internet of Medical Things. This methodology merges protocols to strengthen data privacy and security, facilitating user authentication, efficient data storage, and secure healthcare data transfers within the blockchain network
	[9]	2023	Yes	The authors proposed a new approach for querying blockchain data that employs an encryption-driven strategy alongside an integrated access control system. This method addresses challenges such as search capabilities and potential healthcare privacy breaches
	[10]	2023	Yes	The authors designed an approach to address the challenges of Electronic Health Records (EHR) systems, which need more consistent data handling, limited access and better coordination between healthcare facilities. Their solution involves leveraging the Ethereum blockchain alongside encryption techniques such as the Advanced Encryption Standard and Zero Knowledge Proof Protocol
	[11]	2021	Yes	The authors proposed a blockchain-powered system named SPChain to enhance the sharing and confidentiality of electronic health records. This system speeds up data access and promotes engagement from healthcare establishments through a reputation system. Additionally, it integrates proxy re-encryption to ensure data exchange

(continued)

Table 1 (continued)

Adopted technology	Paper	Year	In the healthcare domain?	Contribution
Metaverse	[12]	2024	Yes	The authors examined how medical education has evolved from approaches to the era, highlighting the significance of the internet and advancements such as virtual reality (VR), augmented reality (AR) and mixed reality (MR). They delved into transitioning from teaching methods to engaging learning environments, leveraging the metaverse for simulation-based instruction and collaborative learning. Additionally, they addressed adopting learning in response to the COVID-19 crisis and its effects on medical education
	[13]	2023	Yes	The authors explored how the Metaverse could interact with internet applications in healthcare. They also mentioned creating a connected healthcare system in the Metaverse, reviewing existing research, and discussing the technology behind it. The study compares classical and newer Metaverse platforms and explores how they could be used in healthcare, such as virtual meetings and realistic simulations
	[14]	2023	Yes	The authors proposed investigating how to integrate the Metaverse into healthcare systems to improve practices and services. This research delves into the Metaverse's features, covering its core technologies and diverse applications in emergency training and practical medical education
	[15]	2022	Yes	The authors explored how a virtual world combining metaverse technology and artificial intelligence known as MeTAI could revolutionize the healthcare industry. By incorporating cutting-edge tools such as reality augmented reality and AI, they suggested ways to use MeTAI for medical imaging and treatment
Blockchain and metaverse combination	[16]	2023	Yes	The authors proposed a privacy-focused approach centred on users in the healthcare metaverse, tackling issues like protecting data and ensuring security. By using decentralized Federated Learning (FL) and a blockchain (cross-chain) FL framework, the study improves data security by using a system that includes a chain and various subchains. This structure enables distributed data training. Moreover, they introduced an Age of Information (AoI) measure and a contract theory model rooted in Prospect Theory (PT) to encourage and optimize data exchange, emphasizing the service providers' service value

(continued)

Table 1 (continued)

Adopted technology	Paper	Year	In the healthcare domain?	Contribution
	[17]	2023	Yes	The authors proposed combining artificial intelligence and blockchain technology in the metaverse to improve healthcare services. They outlined a framework with three environments: the doctor's space, the patient's space and the metaverse environment. In this system,, interactions occur through avatars linked to the blockchain for data management. This approach ensures confidentiality, privacy and reliability by documenting all consultations and securely storing information like images and clinical data on the blockchain. Ai (XAI) models leverage techniques like GradCAM and LIME to analyze this information for disease prognosis and diagnosis, offering understandable outcomes. Blockchain technology's transparency, traceability and permanence further maintain confidence in protecting their personal data
	[18]	2022	Yes	The authors addressed improving Healthcare 5.0 in the metaverse by utilizing blockchain for security and explainable AI for diagnostics. They highlighted the importance of blockchain in ensuring transparency and immutability and how explainable AI builds trust in healthcare decisions. The authors proposed a blockchain system integrated with explainable AI within the metaverse to enable secure and transparent communication among patients, physicians and virtual medical facilities

The following section examines Blockchain technology, covering its concepts, historical progress, main features, and operational functions. It delves into the transformation of Blockchain from a data structure to a platform that facilitates decentralized applications and digital currencies. It discusses decentralization, immutability, and transparency while outlining the processes that support its operations.

3 Blockchain Fundamentals

3.1 Definition and Evolution

Blockchain technology functions as a distributed ledger system. It was initially implemented in 2008 by an individual or group using the pseudonym Satoshi Nakamoto [19]. Initially serving as the public transaction ledger for Bitcoin blockchains, it aimed to ensure transactions without a central authority. Its distinctive feature is structuring data into chained blocks secured with cryptography, enabling transparency and trust. The evolution of blockchain technology, transcending its initial association with Bitcoin, represents a significant leap into diverse sectors. It has transitioned from a trivial platform for cryptocurrency transactions to a dynamic tool for digital progress, promising transformative changes.

Following Bitcoin's demonstration of the practicality of transactions, the underlying blockchain technology started attracting interest across different industries looking to tackle its advantages. A significant milestone in blockchain evolution was the emergence of Ethereum in 2015 [20]. Ethereum built upon the principles of blockchain by introducing smart contracts, which are self-executing agreements with terms directly encoded into the system. This innovation enabled transactions, intricate contracts, and automated enforcement without intermediaries. Also, Ethereum paved the way for developers to create decentralized applications (dApps) on its network, significantly broadening blockchain's scope.

Moreover, the functionality of executing smart contracts gave rise to Non-Fungible Tokens (NFTs), which are unique digital assets verified through blockchain technology. In contrast to cryptocurrencies like Bitcoin and Ethereum's Ether, where each unit is interchangeable with another, NFTs possess distinct characteristics. Every NFT has an identifier proving art, music, and video ownership. The emergence of NFTs has become a trend in blockchain technology. They significantly impact the art sector and digital content creation by offering a way to assign and validate ownership of digital assets.

Furthermore, blockchain technology has expanded its reach into sectors like supply chain management, where it boosts transparency and traceability in healthcare, ensuring secure and efficient patient data management across different platforms. Besides cryptocurrencies, blockchain is the foundation for decentralized finance (DeFi) applications that seek to reshape traditional financial systems with fewer mediators.

The progression of blockchain is marked by its increasing integration into aspects of business and daily life fueled by its core features of decentralization, transparency and security. As technology advances, future developments may encompass smart contracts, enhanced network scalability, and wider regulatory acceptance.

3.2 Blockchain Attributes

Blockchain technology is not just another technological advancement; it is a revolution. Its unique features, including decentralization, transparency, immutability, and security, have sparked a global interest and led to widespread adoption in various sectors [21].

- **Decentralization**: Unlike traditional databases controlled by an entity, blockchain functions on a decentralized network of computers called nodes. This setup ensures that no single authority governs the network, reducing the risks of censorship or corruption. Each node holds a copy of the ledger, safeguarding against any failure that could compromise the system's integrity.
- **Transparency**: Transactions on a blockchain are visible to all participants and cannot be altered once validated. This transparency fosters trust among users, as they can independently verify transactions without relying on a trusted intermediary. Public blockchains allow anyone to access transaction records, enhancing accountability beyond what systems offer.
- **Immutability**: Once data is recorded on a blockchain, changing it becomes highly challenging. Each block does not contain a timestamp or transaction details, but it also includes a hash of the preceding block in the chain. Cryptographically connecting blocks ensures that changing the information in one block would necessitate altering all blocks, making it extremely difficult on an active network due to the immense computational power needed.
- **Security**: Blockchain employs cryptography to safeguard data transactions. Each transaction is digitally signed, guaranteeing that only the digital asset owner can initiate it. This setup guards against fraud and unauthorized activities. Moreover, blockchain's decentralized nature significantly mitigates the risk of hacking attacks commonly associated with systems.

These characteristics position blockchain as a groundbreaking technology for improving systems that demand trust, security, and transparency. Whether in services supply chain management, healthcare, or digital rights management, blockchains' distinct features provide benefits over traditional centralized systems.

3.3 Blockchain Functioning Process

Blockchain is a decentralized ledger that records transactions across various nodes, ensuring transparency and resistance to unauthorized changes. The workflow of blockchain is described as follows (Fig. 2).

1. **Transaction Initiation**: When a user initiates a transaction by transferring assets like cryptocurrency or data from one address to another, they specify the senders and receivers' addresses along with the transaction amount.
2. **Digital Signature**: The transaction is verified with a signature created using the sender's key. This signature confirms that the transaction originates from the sender and has not been altered.
3. **Transaction Broadcasting**: The signed transaction is broadcast to the blockchain network, where nodes pick it up for verification. These nodes confirm the transaction's validity by checking against the sender's balance.
4. **Verification and Block Creation**: Nodes or blockchain miners validate the transaction using consensus mechanisms like Proof of Work or Stake. Once validated successfully, the transaction is grouped and placed into a data block.
5. **Block Linking**: Each new block in the blockchain is connected cryptographically to the block using a hash generated from the block's data.

In the blockchain system, each new block includes a hash that links it to the block, forming a continuous chain of blocks. Before adding a block to the blockchain, all nodes must agree on its validity through a consensus process. This agreement ensures that the state of the blockchain and all transactions are recognized uniformly. Once a consensus is achieved, the new block will become part of the blockchain.

After adding the block, an updated version of the blockchain is shared with all network nodes. This update finalizes transactions by transferring ownership of assets to recipients.

The blockchain's decentralized nature, cryptographic connections, and validation through consensus guarantee its security and permanence. Once transaction details are recorded, it becomes highly challenging to modify them.

The following section presents a comprehensive review of metaverse definition and evolution and outlines its core seven layers, each one and its responsibility.

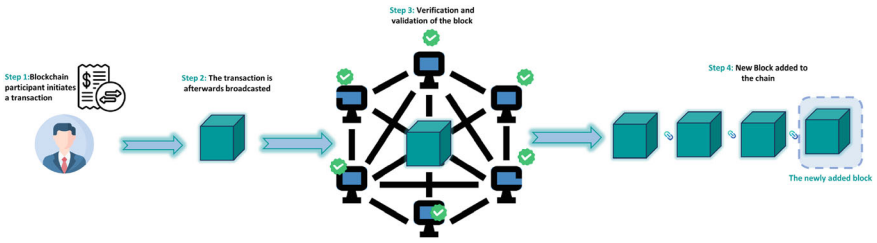

Fig. 2 Blockchain process

4 Metaverse Essentials

4.1 Definition and Evolution

The metaverse represents a shared realm that blends physical reality and persistent virtual spaces, allowing users to engage with one another through digital avatars. It combines reality, reality and the internet to create an immersive environment where digital and physical experiences seamlessly coexist. This space is characterized by its existence regardless of user activity, its ability to accommodate a growing number of users and its capacity for transferring assets between virtual domains and real-world platforms.

The metaverse concept dates back to science fiction literature like Neal Stephenson's "Snow Crash" from 1992 [22], which introduced the idea of a virtual world populated by avatars. This vision sparked interest among technologists, laying the groundwork for worlds to emerge. During the 1990s and early 2000s, virtual environments such as Second Life simulated real-world elements in a space that allowed users to interact, trade and experience different digital lifestyles. With progress in faster internet speeds, advanced reality (AR) and virtual reality (VR) technologies, and enhanced computing power, these virtual worlds have become more immersive and intricate.

The rise of online gaming also shaped the metaverse. Games such as World of Warcraft and Fortnite transformed into hubs where players competed and socialized, traded items, attended virtual concerts, and participated in events within the games' virtual domain.

Today, the metaverse represents a phase in the internet's evolution. It is a virtual world that blends physical and digital realms through ongoing user engagement, advanced AR/VR tech innovations, and a vibrant digital economy. Continuous technological advancements and growing digital connectivity are set to push the limits of what can be achieved in the metaverse.

4.2 Metaverse Layers

The metaverse, a captivating vision of our digital future, is a multifaceted ecosystem. It's a realm of technological marvels comprising seven integral layers that work harmoniously to create an immersive and cohesive experience. Figure 3 highlights the seven primary metaverse layers, namely (infrastructure, human interface, decentralization, spatial computing, creator economy, discovery and experience).

At the base lies the **Infrastructure Layer**, the bedrock comprising the physical hardware and the expansive networks that power the metaverse. This includes cutting-edge 5G, Wi-Fi 6, and the forthcoming 6G connectivity, as well as cloud infrastructures, processors, sensors, and essential materials. Collectively, these components

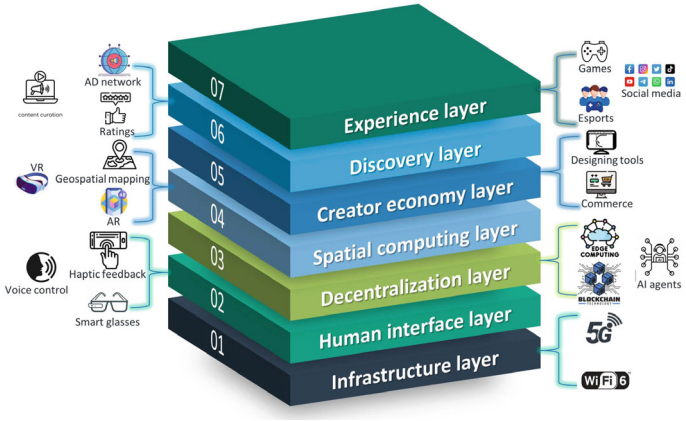

Fig. 3 Metaverse layers

ensure that the metaverse is underpinned by a robust, high-speed backbone capable of supporting complex, real-time interactions.

Above this rests the **Human Interface Layer**, representing the various devices and technologies users use to interact within the metaverse. This encompasses mobile devices, smart glasses, and wearables, all enhanced through haptic feedback systems, voice control, gestures, and even neural interfaces to provide an intuitive and tactile user experience.

The **Decentralization Layer** is pivotal for the metaverse's autonomy and security. It features edge computing, a distributed computing paradigm that brings computation and data storage closer to where they are needed to minimize latency. AI agents, or artificial intelligence agents, streamline processes and employ blockchain, a decentralized and distributed ledger technology, to ensure secure, transparent transactions and interactions.

The fourth stratum, the **Spatial Computing Layer**, integrates the physical and digital dimensions. It leverages 3D engines and VR/AR/MR technologies to render rich, spatially aware virtual environments. Moreover, geospatial mapping grounds the digital experiences in real-world locations, enriching the sense of immersion.

Within the **Creator Economy Layer**, the metaverse holds immense potential. It is a world where users and creators can design, share, and monetize their creations, fueling a vibrant economy. From design software to asset marketplaces, from collaborative workflows to commerce systems, the metaverse offers a wealth of opportunities, underpinning a thriving economic landscape.

The **Discovery Layer** is the metaverse's navigation system, helping users find and engage with content. Through ad networks, social features, content curation, and digital agents, this layer ensures that users can easily explore the vast expanse of the metaverse, finding experiences that resonate with their interests.

Finally, the **Experience Layer** sits at the pinnacle, encompassing the metaverse's content-the digital world's heart and soul. Here, the metaverse comes alive with many

activities and events, from thrilling games and vibrant social networks to exciting esports, immersive theatre experiences, and even virtual shopping. This is where users can truly immerse themselves in a world of endless possibilities, engaging in experiences that range from pure entertainment to educational adventures.

Jointly, these seven layers of the metaverse construct an ecosystem that is not only technologically advanced but also socially vibrant, economically potent, and highly accessible, paving the way for a future where digital and physical realities are seamlessly connected.

The following section discusses blockchain technology's role in the healthcare industry, the growing influence of the metaverse on healthcare services and the advantages of combining both blockchain and the metaverse in healthcare. It explores how blockchain features like improved security and transparency can transform record handling and patient data protection and how the metaverse offers new treatment, training and patient involvement methods. Additionally, it emphasizes how using them together could improve healthcare service quality, effectiveness and patient results.

5 Blockchain and Metaverse in Healthcare

5.1 Blockchain's Importance in Healthcare

Today, healthcare systems worldwide struggle with urgent challenges such as data fragmentation, security risks, and operational inefficiencies. In this context, blockchain technology emerges as a timely and potent solution. Blockchain promises to address these pressing issues effectively with its unique decentralization, immutability, and transparency features. The following are some key advantages that blockchain can offer to the healthcare industry:

- **Enhanced privacy**: Blockchain provides a tamper-proof platform well-suited for handling sensitive healthcare data. Each entry on the blockchain is connected to another, creating a solid chain of blocks, an unchangeable record that enhances patient privacy and safeguards against breaches.
- **Improved Data interoperability**: By establishing a platform for data exchange, blockchain helps overcome the fragmentation in healthcare systems. This allows healthcare providers to access patient records seamlessly across systems, enhancing diagnostics and treatment outcomes.
- **Simplified Operations**: Blockchain technology brings significant efficiencies through its ability to automate and enforce agreements independently. This translates to a reduced workload related to billing, claims processing, and compliance checks for healthcare professionals. Ultimately, this leads to cost savings and quicker service delivery, benefiting the healthcare industry.

- **Prevention of Counterfeit Drugs**: Ensuring transparency in the pharmaceutical supply chain by tracking each stage of a drug's journey from production to delivery. This traceability attribute prevents the infiltration and spread of medications, ultimately boosting patient safety and building trust in healthcare products.
- **Improved research and clinical studies**: Blockchain technology ensures efficient trial data management. It offers a platform for researchers to securely share data, maintaining confidentiality while promoting transparency and data integrity. This characteristic is essential for validating trial results and advancing research.
- **Empowering Patients**: Blockchain technology encourages a patient-centric healthcare environment by enabling patients to control their information. This empowerment allows patients to manage who has access to their health data, thereby enhancing the security of their information and encouraging active involvement in their healthcare decisions. This potential impact on patient autonomy is a significant benefit of blockchain in healthcare.
- **Cost Savings**: Blockchain helps cut costs by removing intermediaries from processes such as claims and payment systems. It also reduces fraud and misuse through increased transparency and secure data handling.

5.2 Metaverse Importance in Healthcare

The Metaverse, a novel virtual reality platform, offers immense potential for the healthcare industry by providing various advantages that can improve patient care, enhance healthcare provider skills and elevate the overall medical experience. Here are the main benefits of incorporating the Metaverse into healthcare (Fig. 4).

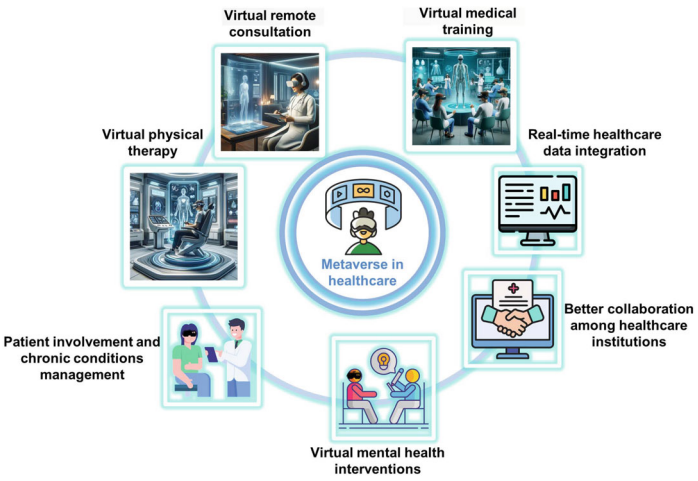

Fig. 4 Metaverse benefits for healthcare

- **Improved Remote Consultations and Telemedicine**: Through the Metaverse, immersive virtual environments can be created where patients and doctors can interact seamlessly despite being physically far. This enhances telemedicine by offering an interactive experience compared to standard video calls. Patients can receive consultations, ongoing care and certain types of therapy from the comfort of their homes, which is particularly beneficial for individuals in areas with limited mobility.
- **Enhanced Training and Education**: Using the Metaverse can transform training and education. Medical students, surgeons, and healthcare professionals can practice procedures in a virtual setting. For instance, surgeons can simulate operations using VR tools that replicate real-life scenarios accurately. This allows for repeated practice without concerns about resource availability or patient safety risks, thereby improving learning outcomes and potentially leading to results.
- **Exploration of Mental Health Interventions**: The Metaverse introduces possibilities for addressing health concerns by offering immersive therapy sessions and support groups. Individuals coping with mental health challenges can utilize virtual reality for controlled exposure therapies in a secure environment. Additionally, the Metaverse enables group therapy sessions where participants can maintain anonymity and comfort, potentially boosting enhanced communication and participation.
- **Patient involvement and management of chronic conditions**: The Metaverse's interactive features can enhance engagement by transforming disease management into interactive experiences. Patients can access health programs, educational activities, and community support groups within this domain. This approach empowers patients, enhances adherence to treatment plans, and promotes a stance towards health management.
- **Rehabilitation and Physical Therapy Innovation**: Innovative methods are employed within the Metaverse to provide therapy and rehabilitation services. Patients recovering from surgeries or injuries can engage in physical therapy exercises tailored to their recovery needs. This platform enhances accessibility to therapy and makes it more engaging and enjoyable for patients, potentially increasing adherence to prescribed therapeutic routines.
- **Improved collaboration among healthcare providers**: The Metaverse has the potential to enhance cooperation among healthcare professionals regardless of their locations. Doctors and specialists can assemble in virtual environments to discuss cases, exchange knowledge, and work together on care without the constraints of physical travel. This can be especially beneficial in scenarios that require input from multiple disciplines or when access to specialized expertise is limited.
- **Real-Time Data Integration and Visualization**: Real-time data from health records, medical equipment, and other outlets can be seamlessly presented in creative formats within the Metaverse. For example, physicians could visualize representations of a patient's anatomy that are continuously updated with information gathered from health monitoring devices. Such capabilities can improve precision and enhance the customization of treatment strategies.

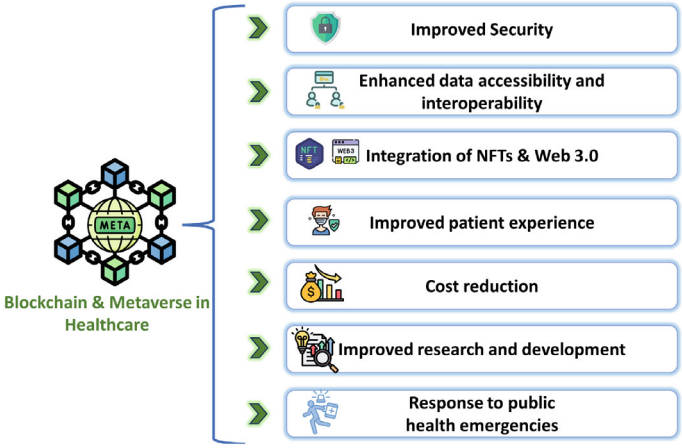

Fig. 5 The benefits of blockchain and metaverse combination in healthcare

5.3 The Intersection of Blockchain and Metaverse in Healthcare

Combining blockchain technology and the metaverse into healthcare systems signifies a groundbreaking shift that offers advantages compared to traditional models and their applications. This fusion does not boost data security and patient care; instead, it reshapes the dynamics within healthcare ecosystems (Fig. 5).

One significant advantage of utilizing blockchain in healthcare lies in enhancing security measures. The decentralized nature of blockchain ensures there is no point of failure, making it resilient against cyber-attacks, a concern in healthcare, given the sensitivity and importance of medical information. Every transaction on a blockchain is linked to the preceding one, forming a solid chain. This proves crucial in healthcare, where maintaining the integrity of records is paramount. Leveraging blockchain technology can mitigate risks related to data breaches, unauthorized entry, and ransomware attacks effectively.

Furthermore, blockchain promotes data interoperability while upholding privacy and security standards. Through distributed ledgers, healthcare providers can maintain precise patient data records from various origins. Also, authorized healthcare professionals can access this information in time, regardless of their location, which is an advancement that facilitates care coordination for patients with complex conditions necessitating input from specialists. Blockchain technology, non-fungible tokens, and Web 3.0 are vital to significant changes in healthcare. NFTs can represent patient records, making them easy to transfer and track while ensuring security and privacy. This could revolutionize data management by allowing medical histories, prescriptions, and test results to be securely accessed. Web 3.0 technologies improve user interaction and data handling in this space, enabling immersive healthcare training, consultations and therapy sessions.

Furthermore, with the support of blockchain, the digital realm offers a new environment for patients. Virtual reality (VR) and augmented reality (AR) can be utilized for consultations, therapy sessions, and even real-time surgeries. This increases access to healthcare services in remote areas and empowers patients to better understand their health conditions and treatments, leading to improved health outcomes. Also, when blockchain and the metaverse work jointly, they can significantly reduce costs related to healthcare operations. Blockchain simplifies classic operations like billing processes, compliance tasks and data storage management. At the same time, the metaverse reduces reliance on facilities by enabling virtual healthcare services and lowering operational costs.

Moreover, combining these technologies allows for the gathering and examining data, which is crucial in advancing healthcare research and development. Blockchain technology guarantees the reliability and security of collected data, while the metaverse offers the ability to simulate trial scenarios without requiring physical resources. Researchers can observe real-time effects by manipulating variables in environments, expediting medical research progress and fostering innovation. Blockchain and the metaverse can also improve response mechanisms during health crises like pandemics. Blockchain enables swift information dissemination across local health networks. On the other hand, the metaverse promotes collaboration among healthcare professionals by facilitating virtual training sessions and simulation exercises, ensuring readiness and fast responses without physical presence requirements.

The next section discusses the changes from combining blockchain and metaverse technologies into healthcare information systems. It compares these systems to traditional ones to examine how this blend improves data protection, patient confidentiality, and service provision. Furthermore, it investigates the possibilities of this synergy, outlining potential advancements and innovations that could transform healthcare even more. It also discusses the difficulties and hurdles that need to be overcome to unlock this integration's benefits fully.

6 Discussion

Traditional healthcare systems are criticized for being inefficient and unequal. The way data is managed centrally creates information silos that make it hard for different healthcare providers to communicate effectively. This lack of coordination can delay diagnosing patients, repeat tests, and overall inadequate patient care. Additionally, traditional systems face security risks with cyber-attacks on hospitals and clinics, putting data at risk. These systems also require many resources, such as large space, staff and equipment, which raises healthcare costs for patients and insurance companies (Table 2).

Therefore, integrating blockchain technology and the metaverse into healthcare can tackle many of these issues. Blockchain's encrypted record-keeping system addresses security concerns in healthcare. This ensures that patient data is secure

Table 2 Comparative table of traditional healthcare systems and blockchain-metaverse integrated healthcare systems

Characteristic	Traditional systems	Blockchain and metaverse combination
Security	High vulnerability to cyber-attacks	Improved security using blockchain decentralization and encryption
Data interoperability	Limited and restricted	Real-time access and high interoperability
Cost	High because of the inclusion of physical material	Low through virtual services and minimized material
Accessibility	Restricted in remote zones	Enhanced through virtual services accessible universally
Patient involvement	Passive and physical consultations	Active due to virtual consultations
Public health response	Moderate response	Fast response due to virtual collaboration
Patient data management	Fragmented data	Secure and flawless using NFTs and blockchain
Processes efficiency	Manual operations	Automated operations due to smart contracts
Innovation and research	Slow due to regulatory restrictions	Fast and solid using virtual testing environments

and cannot be altered or accessed without permission. Another critical benefit is interoperability. Blockchain allows for a single view of data authorized providers can access in real-time from anywhere worldwide. This feature is crucial for delivering excellent patient care and managing conditions that require constant monitoring and adjustments to treatment plans.

On the other hand, the metaverse revolutionizes interaction by incorporating reality and augmented reality into medical consultations and treatment. This advancement allows for the simulation of procedures, immersive therapy sessions for educational purposes, and virtual consultations that save time and limit the need for travel. These advancements improve the experience and expand healthcare accessibility to remote areas and underserved communities, bridging a crucial gap in traditional systems. Moreover, financial efficiency is boosted as blockchain simplifies administrative tasks such as billing and managing medical records, reducing overhead expenses. The metaverse aids in cost savings by reducing the necessity for office spaces and enabling healthcare providers to deliver services in a virtual environment.

The fusion of blockchain and the metaverse within healthcare shows promising potential but encounters notable obstacles. For instance, the scalability of these technologies within healthcare systems still needs to be tested. Since these technologies demand resources, scaling them to serve millions of users without compromising

performance or security poses a technical challenge. Another challenge is regulatory compliance. The healthcare sector is a regulated industry that requires careful navigation of intricate legal frameworks when integrating new technologies such as blockchain and the metaverse while adhering to data protection laws. Another critical challenge is user acceptance. The effectiveness of these technologies depends not only on their strength but also on how readily healthcare professionals and patients embrace them. Convincing healthcare institutions and overcoming resistance to change among those familiar with conventional technology is crucial for broad adoption. Furthermore, privacy concerns within the metaverse are particularly significant. Although blockchain can enhance security for data transactions, the metaverse's immersive nature raises questions about the collection and utilization of data in settings. It is essential to ensure that privacy protections evolve alongside progress. In moving with this integration, it is necessary to prioritize testing, establish transparent regulatory guidelines for scalability, and develop plans to build user confidence and encourage widespread use.

7 Conclusion

The fusion of blockchain technology and the metaverse heralds a new era in healthcare, promising to resolve numerous inefficiencies and security risks inherent in traditional systems. Blockchain ensures healthcare data is secure, unalterable, and accessible in real time to authorized individuals, irrespective of location. This enhances the protection and privacy of information and facilitates patient care, promoting better coordination and efficiency. The metaverse opens new avenues to engage patients and deliver healthcare services by harnessing virtual and augmented reality technologies. It transforms interactions into immersive experiences, offering more inclusive and easily accessible healthcare services that can significantly benefit broader populations, particularly those in remote or underserved areas.

However, there are limitations to overcome. Challenges such as scalability, regulatory compliance, user acceptance, and privacy concerns pose significant barriers that must be surmounted to integrate these technologies into mainstream healthcare successfully. To tackle these challenges effectively, it is imperative to develop robust solutions, establish clear regulatory frameworks that provide support, and enable trustful relationships with all healthcare institutions. For future work, we aim to build a blockchain-based healthcare system that integrates the metaverse to promote security and better patient care.

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Applications of the Metaverse in Medicine and Healthcare

Vishnu Mittal, Pushkar Upadhyay, and Anjali Sharma

Abstract The development of simulated or virtual realm known as the "metaverse" is underway, with the goal of fostering more immersive interactions between users and digital objects. The convergence of digital twins, blockchain, and telepresence, which are three significant technical advancements, is driving this development. Telepresence refers to the ability of individuals to virtually "be together" even when they are not in close proximity to one another. A digital twin is an electronic replica or virtual model which utilise real-time data to simulate the behavior and monitor operations of a medical device or a patient, sometimes even a healthcare center. Patients can use blockchain technology to ensure the security of their private medical records. The usage of metaverse might be advantageous in a range of medical and healthcare situations, such as virtual counseling, medical education and also training, patient awareness, medical research, pharmaceutical creation, aid, and experimental medicine. Metaverse is poised to bring about more accessible, efficient, and personalized medicine and healthcare, resulting in improved patient compliance and somewhat economic in a way. Use of metaverse in medicine and healthcare sector requires careful consideration of privacy as well as ethical issues, alongside social, technological, and legal considerations. Despite these challenges, the potential of metaverse for use in medicine as well as healthcare sector seems bright, and new laws specifically designed for metaverse should be prepared to be helpful in minimizing any negative effects.

Keywords Metaverse · Healthcare · Medicine · Digital · Patient

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1 Introduction

Neal Stephenson used phrase "metaverse" initially in his 1992 novel "Snow Crash." It defines virtual reality (VR) that extends beyond the physical world and offers a different virtual environment where users can create and share their own activities. Consequently, metaverse appears to be as different 3rd Dimension reality inside a network that is accessible with special technology, such as audiovisual equipment or glasses [1, 2]. Characterized by convergence of virtually augmented digital reality and physical reality, it is a type of communal virtual shared area centered on social interaction between population. By projecting an alternate digital identity into the environment and context that results from both of the virtual and physical worlds, real people can use the metaverse to express their personalities and habits. Four technologies forms a foundation for metaverse: virtual reality (VR), real-time augmented reality (AR), a combination of two which is mixed reality as well as extended reality which is also called XR [3, 4]. VR or Virtual reality is a contemporary technological service enables users to immerse themselves in a simulated environment produced by digital equipment, allowing them to experience a real-world situation; AR or Augmented reality is a technical aid that provides a virtual environment in which a two or three-dimensional virtual item interacts through real place; MR or mixed reality is basically a technological service that integrates data from both physical and digital realms, resulting in creation of a simulated environment that seamlessly combines these two domains [5, 6]. Ultimately, MR serves as a precursor to virtual reality. XR or extended reality integrates virtual reality (VR), augmented reality (AR), and mixed reality (MR) into a novel kind of reality [7].

One new technology that could revolutionize a lot of industries in future is metaverse. The metaverse, A virtual environment which is created in order to enable more immersive interactions between users and digital objects than can currently be achieved through conventional screens and interfaces. It is a component of Web 3.0, which uses artificial intelligence (AI) and blockchain technology to create a decentralized web [8, 9]. Within the gaming industry, the metaverse is already evident in games like World of Warcraft and RuneScape, as well as in massively multiplayer online role-playing games (MMORPGs) like KoGaMa, Growtopia, Minecraft, Genshin impact. Travel and Tourism, advertising, conveyance, and finance are among the other sectors and industries that are establishing a metaverse presence, emulating the gaming industry [10]. In 2021, Facebook even changed the name of the business it owned to "Meta," generating more buzz about the metaverse that already existed. A metaverse ecosystem made up of elements from the fields of economy, ecology, technology, and society, as well as an unofficial architecture [11, 12]. Although some of its applications are still in their early stages, the healthcare industry is already adopting this metaverse trend as well [13].

1.1 Significance Behind Metaverse

Three significant technology developments are coming together to form the metaverse. While these trends alone may have an influence on healthcare, when combined, they might open up whole new avenues for care delivery that could significantly reduce costs and improve outcomes for patients [14]. These are blockchain, digital twin, andand telepresence/telemedicine. The capacity of individuals to virtually "be together," even when they are not in close proximity to one another, is known as telepresence. This can be accomplished using augmented reality as well as virtual reality, or some other techniques. In VR,user is fully submerged [15, 16]. In AR, user sees a real picture mixed with an artificial one. In addition to augmented and virtual reality, Kye et al. distinguish between two other forms of the metaverse: the mirror world, which replicates the reality while incorporating as well as disseminating the whole information about the outside world, and lifelogging, which records, stores, and shares information about commonplace events and people [17, 18]. Telemedicine, or the practice of providing medical treatment remotely, is the main use of telepresence in the healthcare industry. Since the COVID-19 epidemic, telemedicine has been more popular. The digital twin of a physical product is composed of three primary components: the virtual product, actual product, and data and information links that connect them [19, 20]. The digital twin (DT) in healthcare might be a virtual image of a patient, a piece of equipment, or an actual hospital. One form of Distributed Ledger Technology (DLT) that has gained notoriety is blockchain, which serves as the foundation for cryptocurrencies. It keeps track of transactions while preserving the original data and extra information protected by many data security layers, such as encryption [21]. Blockchain is a key component of metaverse because it may be used as a storehouse for data within the metaverse and as an economic system to facilitate trade of non-fungible tokens (NFTs), which is one way to connect metaverse with outside world. Blockchain is particularly interesting to the healthcare industry because it may offer a safe "wallet," similar to a cryptocurrency, for the safe storage of patient information and other sensitive data. The patient regains control because no single entity controls the data due to its decentralized architecture. Transparency and immutability are introduced into healthcare through the usage of blockchain [22]. The patient or a medical professional could be the end user of metaverse in a number of medical and healthcare contexts, including virtual consultations with doctors, medical instruction and instruction, patient education, medical research, medication growth and development, treatment and support, and lab medicine. provide even more thorough listings of possible uses [23]. The metaverse has promise for facilitating more accessible, efficient, and individualized healthcare, which might lead to better patient outcomes and lower costs. The ability of the objects (the "things") to transmit information about themselves and to get aggregate data gathered from other objects allows them to become identifiable and intelligent. Therefore, by means of data received and/or transmitted through network, alarm clock can be programmed to sound earlier in anticipation of inclement weather or traffic congestion; the athletic accessories can transmit data such as timestamps, performances, speed, and distance

covered, enabling timely competition with athletes situated in different geographical regions; and the intelligent medicine containers can alert the patient or their family members in the event that they neglect to take their prescribed medication [24, 25]. Thanks to their network connections, all objects can now play an active role in an individual's life. This led to the creation of what are known as "smart" objects, which are defined by attributes like identification, connection, localization, data processing, and interaction with the outside world. People have relied on equipment and gadgets (computers and cell phones) to help them in everyday activities for decades [26, 27]. The distinction is that these tools are now "smart," meaning they can act somewhat independently and are connected to the outside world. By giving objects and locations in physical world an electronic identity, Internet of Things aims to create a map of the actual world. Items and locations that have QR codes or radio frequency identification (RFID) labels on them may share information with mobile devices like PDAs, tablets, and phones as well as the internet [28, 29]. To put it another way, Internet of Things (IoT) is technology used to generate metaverse and obtain data required for its ongoing maintenance, or the link connecting the actual world and the metaverse. Hence metaverse is set up as a digital environment that is still mostly unexplored or, in any case, will be built gradually [30]. Users will be able to move through reproductions that are also created in their likeness (Avatars and digital twins), which are essentially accurate graphic representations of themselves that allow them to communicate in real time with other digital individuals who are all unique. Thus, a dimension where multiple technologies such as VR, AR, AI, IoT, and others converge and enhance one another to articulate both digital and physical worlds [31].

1.2 Metaverse Essential Ideas

Gaining a thorough understanding of validity and viability of using metaverse in medicine comprehending the underlying idea is essential. The core research on the metaverse, its enabling technologies, and its implications will be covered in detail in the part that follows [32].

1.3 Overview of Metaverse

The concept of metaverse has been around for about thirty years, ever since internet was first developed. But the metaverse has only lately seen significant expansion, thanks to the amazing developments in 3D game technology. The portmanteau word "metaverse" is derived from Greek prefix "meta," which means "beyond" or "transcendent," and suffix "verse," which means "a universe or realm." Neal Stephenson initially presented the concept in "Snow Crash," one of his science fiction books from 1992. [33] In IT industry, "metaverse" has been a common term of use in recent times.

The announcement made by Mark Zuckerberg, the CEO of Facebook, in October 2021 that the company was renaming as "Meta" and that it will give priority to the development of the metaverse has furthered this tendency [34].

1.4 Growth of Metaverse

It wouldn't be an exaggeration to say that metaverse is the biggest digital breakthrough of the future and a logical successor to modern internet technology, given its enormous potential and the exponential development it has seen [35]. Many major tech companies, including Microsoft, NVIDIA, Facebook, Tencent, Bytedance, and Unity, have already announced their entry into metaverse, demonstrating their interest in this innovative field has the potential to completely change digital world. Industry estimates indicate that the metaverse market would see a huge boom, with a forecast value increase of USD 800 billion by 2024, from USD 500 million in 2020. According to predictions, the augmented reality industry is expected to grow at a far faster rate than the virtual reality market, reaching a staggering $855.3 billion by 2027 [36]. Furthermore, evolution of metaverse in healthcare has changed conventional medical procedures. The COVID-19 epidemic has caused a disruption in the traditional method of monitoring patients' well-being via in-person contacts. As a result, telemedicine has become a popular alternative. Telehealth uses digital tools including email, texting, video conferencing, and phone conversations to provide healthcare remotely. Its ubiquity has increased dramatically; in 2020, 95% of US healthcare institutions were prepared to provide telehealth services, up from 43% before to the pandemic [37]. The integration of technology and healthcare is represented by telemedicine, which includes digital medicine, e-health, telehealth, and m-health.

1.5 Definitions of Metaverse

In terms of technology Metaverse is a virtual reality simulation goes beyond conventional 2D interfaces to provide a completely immersive 3D world that accurately depicts real-world settings and events. In spite of the fact that the idea has been discussed widely, a clear-cut definition of the "Metaverse" is still unclear [38]. There has to be more unanimity since various specialists have provided differing explanations of this term. Some scholars have defined Metaverse as an immersive three-dimensional community setting where people may interact with one other via avatars and participate in a variety of social, cultural, and economic activities [39]. However, another viewpoint refers to it as a "virtual world," imitating actual world's physical and geographical features and establishing a digital network environment in which people are represented by avatars [40].

2 The Metaverse and Medicine

Medical applications of the metaverse are highly relevant, and medical IoT, or medical Internet of things, refers to the artificial model used in medical applications, which is made possible by specific devices like AR and VR glasses. The current coronavirus disease 2019 (COVID-19) pandemic has proven very beneficial to spread and advancement of technology for ever-more-advanced "remote" telemedicine. People were obliged to transition from direct doctor-patient interaction to an electronic one centered largely on videoconferences due to the requirement to preserve social separation [41]. This approach may be ideal for consultations do not technically call for a physical examination to take place in person; on the other hand, absence of physical touch between the physician and patient may lessen the empathetic relationship that often forms during a traditional medical examination. With certain gadgets like gloves with the right sensors, the metaverse can partially get over this obstacle in the setting of a three-dimensional world where tactile sensations are integrated with visual and aural information. Additionally, all of patient's medical and scientific data, diagnosis pictures, and full electronic records would be visible to the doctor through use of smart glasses owing to augmented reality, negating need for the doctor to get this information from a computer. Additionally, system will possess the capability to pinpoint errors during diagnostic-therapeutic process, or utilize specific smart devices, such as mobile phones, smartwatches, and vital parameter detectors, to signal potential non-compliance with assigned therapy by the patient. In numerous circumstances, Internet of Things (IoT) has demonstrated its effectiveness in serving patient population. One prominent illustration of this phenomenon is the Asthma Prevention Application, that was created inside the United States with the purpose of doing extensive healthcare research and monitoring air pollution in real-time. Through the examination of patients' digital asthma diary data in combination with atmospheric information, this application has the capability to forecast acute asthma episodes, therefore making a valuable contribution to the prevention of both primary and secondary asthma. Toshiba, a Japanese company, has created an artificial intelligence gadget including wrist monitors and a palmtop that enables the analysis and monitoring of the user's welfare, operations, as well as their habits on a daily basis. This application exemplifies another instance of a MIoT (Internet of Things) implementation. This gadget offers personalized reminders and guidance for maintaining a well-balanced and nutritious diet, as well as engaging in regular physical activity, based on the individual's unique requirements. Artificial intelligence has been identified as a significant factor in facilitating behavioral modifications and mitigating the likelihood of lifestyle-related ailments, as shown by its ability to analyze several physiological parameters like arterial pulse, movement patterns, heart rate, and other skin related activity. When it came to identifying user behaviors like eating and exercising, the program attained 90% accuracy. As a result of pushing the boundaries of digital care pathways as a tool for doctor-patient communication, virtual hospitals have been established in the metaverse. One such hospital is Hospital Alfa in virtual city of Aimedis Health City, where medical professionals and patients from various

backgrounds come together to exchange knowledge and experiences. The goal of the health authorities' current "real world" initiatives is to concentrate resources that is, technology and skills in reference and highly specialized centers. Patients living in outlying locations and far from the center of excellence for medical treatment might face challenges as a result of this concentration of care, particularly the aged and weak with little autonomy. Because of its three key features complete perception, dependable transmission, and intelligent processing MIoT may legitimately help the doctor's work in this situation. A faithful avatar or "digital twin" of patient a twin virtual copy of patient could be created via VR integration with intelligent medical devices. This possibility, bolstered by the availability of modern diagnostic tools like positron emission tomography and computed tomography, could at least partially make up for the absence of a direct patient-doctor relationship [42].

Since 2018, China has embraced another usage of metaverse in medicine, using a MIoT model for a lung cancer screening program. The novel screening method analyzes tomographic picture of subcentimeter nodules found in a patient with those from an image archiving system using a network of appropriate processors. In this manner, a successful screening strategy based on contemporaneous comparison with prior tests and real-time radiological assessment was developed. Big data-based management technologies were used to enhance the early identification of pulmonary nodules via the creation of PNapp5A, a type of application based on five-step evaluation of pulmonary nodules. Chinese Alliance Against Lung Cancer (CAALC) has implemented this artificial intelligence system in 900 centers across the country. Fudan University-Zhongshan Hospital data indicates that the system has been successful in detecting pulmonary nodules at an early stage, with average age of diagnosis reduced from 63 to 50 years [43]. Furthermore, among all patients undergoing surgery, early diagnosis with this model accounted for 60.3%. Dr. Chunxue Bei coined phrase "human–computer multidisciplinary team" in response to this event, highlighting the communication and cooperation between the doctor and artificial intelligence the latter of which is seen as almost an independent creature with its own identity and autonomy. This innovative method made it easier to standardize the detection, identification, and treatment of nodules of ambiguous origin and early-stage lung cancer. Based on these first situations, we believe that the metaverse may have a wide range of possible uses in medicine [44]. Applications of metaverse-related technology appear extremely real in the fields of psychology, psychotherapy, and rehabilitation. Techno Village Rehaveware, a virtual reality rehabilitation program designed to help people with brain disorders including stroke, Parkinson's disease, and brain surgery regain their diminished motor function. It is anticipated that patients' desire to exercise would rise along with their clinical outcomes when they engage with IoT-type products, such as globes or smart balls. Anticipated applications include the psychological therapy of dementia patients, children and adolescents afflicted with severe mental disorders, and those afflicted with familial violence, in the future, made possible by the capability of creating digital entities parallel to actual world [45]. Artificial intelligence is also being used in the metaverse for surgical purposes. 900 km away, Portuguese surgeon Dr. Pedro Gouveia and his Spanish partner, Dr. Rogelio Andrés-Luna, utilized the metaverse

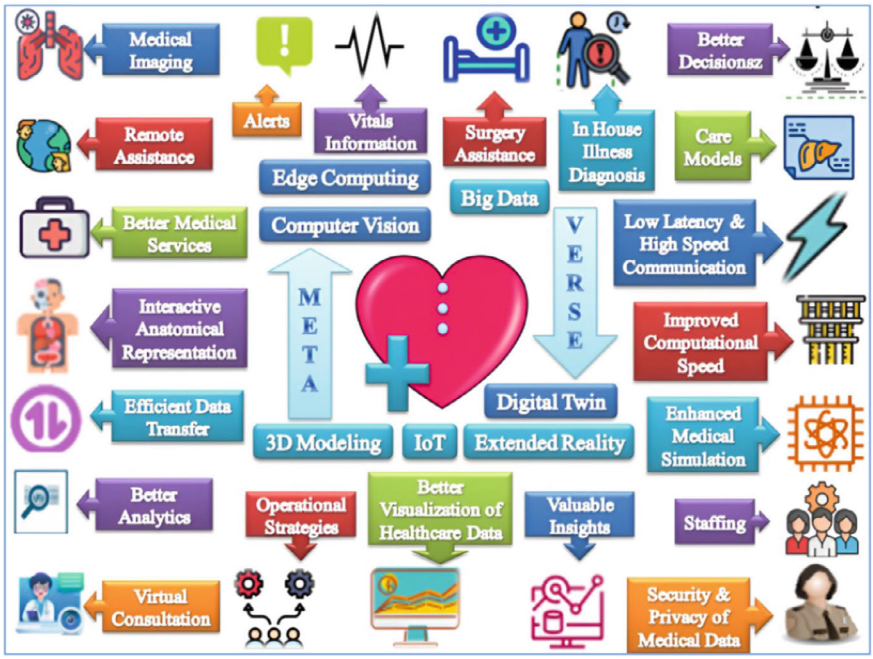

Fig. 1 Enabling technologies of metaverse for healthcare

to mimic being in same operating room at the Champalimaud Foundation's Breast Unit in Lisbon. Dr. Gouveia wore Hololens, which are augmented reality glasses. He was able to see the person who was in front of him while simultaneously displaying diagnostic photos and clinical information onto proper glasses. In this situation, 5G technology has shown to be essential, surpassing 4G technology's drawbacks (such lag time). Artificial intelligence and virtual reality appear to offer enormous promise in the domain of surgery. They would allow operators to fully immerse themselves in the procedure itself, in addition to facilitating remote interventions. In this approach, AR would play a key function. The surgeon will don smart glasses that can track any changes in critical parameters in real time and provide him all the information he needs to perform better without requiring him to look away from the patient or the operating field. Furthermore, having access to virtual reality might be a useful aid in surgery planning [46] (Fig. 1).

3 Potential Application of the Metaverse for Healthcare

It is much easier to provide comprehensive healthcare when "handicraft workshop model" of medicine in which diagnosis and treatment vary from doctor to doctor and hospital to hospital is compared with Metaverse. In a whole healthcare scenario,

choices will be made based on recommendations from specialist and outcomes from many auxiliary technologies available in Metaverse [47]. The Metaverse has several applications in field of health, ranging from assessment and diagnostics to research and insurance. A few potential Metaverse uses could gain traction soon include virtual exercise, virtual biopsy, virtual therapy, and virtual warning response. Virtual biopsy is a non-invasive method of characterizing cells using image processing. Virtual physiotherapy would aid recovering patients with their motions and movements, which would be beneficial [48].

3.1 Medical Diagnosis

Medical assessment is process of interpreting a patient's indicators to determine their medical status. When Metaverse is integrated with healthcare, a number of cutting-edge technologies such as blockchain, extended digital twins, 5G, AR and VR enabled MIoT models, and so on are used to accurately diagnose a patient's medical difficulties. In order to offer everyone with high-quality, inclusive healthcare, "expert consensus on Metaverse in medicine" research explains how and why Metaverse may be used to several healthcare domains [49]. When accessible via AR/VR glasses, MIoT may lessen challenging obstacles encountered in healthcare settings by facilitating holographic construction, modeling, real-world and virtual world communication, and merging. The authors have provided a thorough analysis of holography's applications in medicine. This makes it possible for a treatment plan to adhere to guidelines established by medical associations. The efficient storage, trading, and programming of health-related digital assets across several platforms will be made feasible by Metaverse's integration of blockchain technology and distributed ledger technology. This will enable data to be used to identify a variety of medical issues with more knowledge and accuracy. The authors have investigated a variety of Metaverse applications in optometry. There was also a research on use of blockchain technology to ophthalmologic use cases. "BlockNet" is a secure multi-dimensional data storage system improves data dependability of digital twins by using blockchain technology. Here, a "nonmutagenic multidimensional Hash Geocoding" technique is used to successfully sort multidimensional data. BlockNet could be useful for small-scale medical research. Since diagnosis is fundamental process determines kind of therapy and medications to be administered, using Metaverse in diagnosis will significantly aid in overall quality improvement of all other phases [50].

3.2 Patient Monitoring

The integration of blockchain, digital twinning, and telepresence will provide tremendous advantages for the Metaverse in healthcare, particularly with regard to patient monitoring. Medical services are provided remotely using telepresence in medicine,

often referred to as telemedicine. A virtual, digital model that is made utilizing actual data from an item, system, or person to help understand more about that real-world counterpart is called a "digital twin." These patient test dummies may be used in emergency scenarios to determine how patients will react to procedures or medications even before they are given to them in real life [51]. Using blockchain technology helps store and transport medical data securely, preventing tampering and putting it at risk. This is because medical data is very sensitive and significant. If these three elements are able to function as a cohesive unit, then patient monitoring may be efficiently given. But as technology advances and Metaverse emerges, healthcare industry will gain greatly from creation of virtual worlds that can cure patients even if they are on different continents. When it comes to patient monitoring, AR/VR systems provide the impression of "being at" location. This has significance not just for the communication between medical professionals and patients, but also for the relationship between the patient and his relatives. The Metaverse may facilitate a sense of "being together" for patients, because family can have a significant positive impact on a patient's overall health, even if families are geographically separated. With excellent interactions between patients, healthcare providers, and family members, as well as a good atmosphere created for patient, patient monitoring via the Metaverse may thereby greatly enhance a patient's state of health [52].

3.3 Medical Education

A significant turning point in history of medical education is Metaverse. The technologies that are leading Metaverse in medical education include IoT, blockchain, AI, AR, and VR. Blockchain's unique identifying tag aids in the identification of data in the BC-based Metaverse, demonstrating contribution of AI, blockchain, and Metaverse to medical treatment. The Metaverse is an artificial intelligence (AI) and blockchain-based virtual environment that exists beyond the boundaries of the physical world. Even in a hectic clinical setting, these tools help medical students concentrate, engage in meaningful conversation, communicate in-depth, and enjoy themselves more. In traditional teaching techniques, medical students visit a patient with their tutor, and relevant medical information is then given and debated with class. Virtual reality is being used by physicians for a variety of purposes, including as instructing medical students and performing examinations during colonoscopies, in addition to surgery. The need to engage and comprehend anatomy intuitively in order to enhance patient care is the unifying theme. Virtual reality is a useful tool for teaching body structure to medical students and many clinicians. The human body may be thoroughly examined, with the bones, neurological system, muscles, and much more included. The caliber of aspiring physicians is improved and special opportunities are presented by this kind of education [53]. This technology gives the surgeons X-ray vision during augmented reality procedures. With virtual reality (VR), users may recreate the anatomy in 360° for a particular patient and show them the surgical plan for their procedure. By using this method, you may guarantee

patients' confidence while also enhancing your grasp of therapy. The COVID-19 epidemic caused significant disruptions to medical practitioners' and students' education. The volume of patients, the number of surgeons on staff, and the opportunity for in-person training were all impacted by pandemic crisis. A digitally created replica of the actual world is known as Mirror World (MW). MW is an independent virtual environment built on a block chain, in which application-related data and appearance are integrated and reflect as if they were in a mirror [54]. The actual world is more practical and effective because to the MW. Representative mirror worlds that are used in education include "virtual educational spaces" and "digital laboratories," which are constructed in different mirror worlds. Among the examples of MW applications employed in realm of medical education are "virtual educational spaces." The MW simulation has been implemented by the authors in medical education. Video recordings of the various portals, including the operating room, classroom, and meeting room, are integrated into the MW simulation. The student community benefits from the many portals in various ways. The operation room portal provides a variety of perspectives for the student body to comprehend and engage with the surgery room setting. The meeting room portal seats the largest number of participants for discussions, while the class room portal enthralls the student body with lectures. The goal of this computer lab is to fold amino acid chains in proteins for David Baker's protein structure research group at University of Washington. There was a magazine article mentioning accomplishment of 60,000 individuals in 10 days. The surgical room, dentist office, emergency department, and general care clinic may all use augmented reality at some point. For example, it might be used by medical professionals to schedule intricate procedures like cosmetic surgery. Additionally, they might utilize it to direct them throughout other types of procedures [55].

3.4 Surgeries

The Metaverse is rapidly emerging as a crucial component of medical technology, particularly for surgery. Presently, operating room physicians are becoming more proficient and prepared with use of haptic gloves and virtual reality headsets replicate actual surgical procedures. Surgeons may find it simpler to operate with augmented reality since it makes information retrieval easier. Through application of 3D virtual pictures over a patient's body, augmented reality has potential to provide clinicians easy, rapid, hands-free access to patient data. Teachers might instruct pupils in intricate medical procedures in three dimensions inside the Metaverse [56]. The authors present a concept for a device would conduct maxillofacial bone healing using virtual reality. The product design assists practitioners in creating virtual plans by allowing patient information to be superimposed. The authors explain how Metaverse technology speeds up spine surgery. Spine physicians have been forced to use high radiation dose rate technique known as Minimally Invasive Spine Surgery (MISS) for last 20 years. A dearth of clear instructions and indirect imaging are driving digital revolution in spine surgery [57]. It is become more and more well-known because

of its minimal radiation dosage and effective analysis. Personal devices (IoMT) are used to collect patient data, which facilitates convenient patient monitoring. In field of healthcare systems, using these Metaverse supporting technologies will benefit patients, physicians, and students alike. The aneurysm wall, parent artery, brain, and even aneurysm rupture may all be felt by computer. Furthermore model facilitates trainee neurosurgeons' comprehension of anatomy of aneurysm patients. Users may encounter minute physical aspects such as sensation input due to way model is constructed [58].

3.5 Medical Therapeutics and Theranostics

Medical therapy is branch of medicine deals directly with illness treatment. One subset of digital medicine offers evidence-based therapeutic interventions is called digital therapeutics (DTx). The Digital Therapies Alliance classifies products "offer patients evidence-based treatment approaches guided by superior software programs to prevent, control, or treat a medical illness or disease" as digital therapies. This entails maintaining patients' physical and mental health by using a variety of digital technologies [59]. The authors provide a summary of the historical developments and potential applications of digital therapies. On the other hand, medical theranostics is a synthesis of words therapies and diagnostics. The writers submitted an intriguing study on the assessment of the word "theranostics" and its many meanings. With aid of underlying technologies, use of the Metaverse in therapies and theranostics may significantly alter the medical sector. By forcing patients to engage in physical activity, Metaverse may enhance their physical health. Digital therapeutics is becoming more significant in the healthcare industry as it eliminates the need for pharmaceuticals to treat patients. One such technology can process, analyze, visualize, and understand photos and movies is computer vision. Integration of technologies like AR, VR, ER, blockchain, AI, and computer vision may propel telemedicine to new heights via the Metaverse, which is the medical industry's vision of the future. The current electronic health record (EHR) may be used to construct a patient's digital twin, from which a 3D simulation can be produced [60] (Fig. 2).

4 Ongoing and Upcoming Projects

Three key channels will power the healthcare metaverse: digital twins, blockchain, and telemedicine. This section will cover the numerous Metaverse initiatives that are now underway or planned that are being carried out or publicized by internationally recognized healthcare organizations [61, 62].

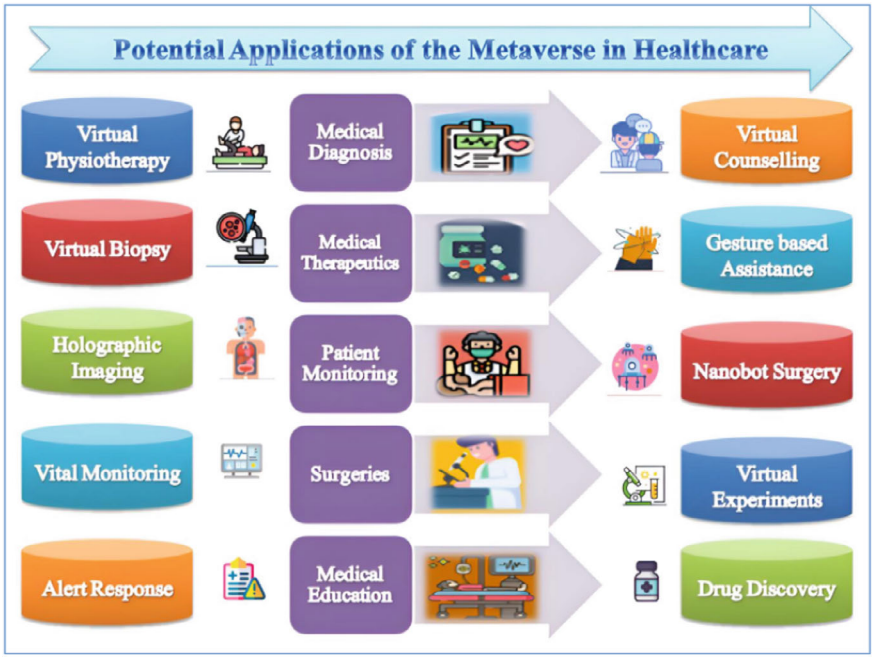

Fig. 2 Potential applications of metaverse in healthcare

4.1 Healthify

HealthLand.io, often referred to as Healthify initiated a Block-chain Metaverse project with aim of offering their clients virtual clubs, encounters with heroes, mental and physical wellbeing, and health excursions. Additionally, this initiative would enable patients and clients to access online retailers and healthcare professionals to create online gyms. The goal is to create a virtual space where individuals from all around the world unite for a good cause, regardless of their ethnicity, religion, or country of origin [63].

4.2 Dehealth

A decentralized Metaverse has been envisioned by the British group DeHealth, with the goal of streamlining the healthcare industry. Virtual reality (VR), augmented reality (AR), and mixed reality (MR) will all be expanded by this technology. With the help of this platform, patients and physicians will be able to work together virtually, communicate with one another, and make virtual income by selling their private

medical records. Additionally, this project will use a revolutionary web 3.0 protocol foundation to revolutionize healthcare service accessibility globally [64].

4.3 Bump Galaxy

A metaverse prototype for mental health services called Bump Galaxy was created on Minecraft. Through the use of gaming environments, this study seeks to alleviate patients' mental health concerns. In addition to giving the patients a sense of safety and support from society, "game world therapy" may help them get over trauma, despair, or anxiety. Through this bottom-up approach, the deep hypnotic visions will foster mental toughness and communal well-being [65].

4.4 Accuvein

The vein imaging project AccuVein will significantly increase vascular entrance rate and turn out to be a revolutionary tool for physicians, neurosurgeons, and patients alike. This will increase annual savings after clinical procedures and increase the success percentage of first-time vaccinations. Patients won't have to worry about bruising after vein access procedure, and physicians will be able to see a huge, intricate network of blood vessels. This work will undoubtedly improve safety and quality of medicines for time-sensitive healthcare applications [66].

4.5 Hintvr

A new Metaverse platform called HintVR was created by California-based software startup 8Chili to assist patients, physicians, surgeons, clinical staff, paramedical personnel, and content marketers. Experts in 3D visualization may utilize enhanced picture guidance during surgery. They may also establish fresh and engaging connections with patients both before and after surgery [67]. As such, it may serve as a solid foundation for the following:

- Physicians to streamline consultations
- Surgeons to execute minimally invasive surgeries with efficiency
- Patients to comprehend diagnosis, treatment options, and testimonies
- Medical and paramedical personnel should effectively adhere to all professional instructions
- Effective learning for trainees via immersive 3D training.
- Material curators may easily choose material and make money from it [68].

4.6 Healthblocks

The goal of the Dutch startup project HealthBlocks, which is based on the IoTex Blockchain, is to eliminate healthcare disparity worldwide. It may help the patient in addition to having the opportunity to monitor them remotely. Decentralized identities for smart devices will result in a fresh ecosystem with a high degree of security and privacy. Users from all over the globe will be able to change their daily bad behaviors and embrace a healthy lifestyle in order to receive prizes using this Web3 Metaverse application. Higher scalability, faster transaction times, and less transaction costs are what this initiative claims to provide [69].

4.7 Other Projects

Microsoft's initiative "Mesh," which aims to revolutionize medical education and training worldwide, will soon be implemented. In the meanwhile, Holoportation and avatars for medical services may be created by integrating Microsoft's "HoloLens 2" with Azure Remote Rendering. Additionally, 3D magnetic resonance imaging (MRI) scans may be used by healthcare professionals to consult with specialists remotely, significantly improving the quality of healthcare procedures [70]. One of the top companies creating minimally invasive procedures is Intuitive Surgical. Ihas come up with "IRIS" solution, which uses AR/VR technology to teach and train doctors and give experts from far away access to important clinical imaging data. While that was going on, Global Healthcare Academy (GHA) and 8chili joined forces to offer medical training & teaching through Metaverse [71].

5 Application Areas

5.1 Medical Education and Training

Metaverse, with its immersive virtual reality experiences, offers a promising solution for providing healthcare providers with training and simulation opportunities without jeopardizing patient safety. In fact, surgical simulations in VR have been proposed as far back as the previous century. There are many solutions available today that make virtual reality training and simulation easier. A touchscreen display and VR headset with controls may be used to edit and examine 360° VR models created from volumetric scans, such as CT and MRI images, via Surgical Theater's Precision VR platform. These models can be seen from any angle [72]. VR training is available on MetaMedicsVR platform for medical experts such as surgeons, nurses, and other healthcare workers. Students get quick, individualized feedback from these VR instructional systems. Researchers have demonstrated that the successful piloting

of metaverse games utilizing avatars to act out medical scenarios in preclinical as well as clinical medical education has produced better learning outcomes as well as an increase in student engagement, participation, and teamwork in a risk-free setting. Immersion learning technology is a fast-developing field that might soon revolutionize medical education. As shown by recent surveys, a large number of students nowadays choose virtual learning environments over brick-and-mortar ones. Apart from simulation and training systems, VR reference works are also available. One example is Clinical Augmented Intelligence's BodyMap, a clinically realistic 3D virtual reality depiction of the human body intended for medical education [73].

5.2 Patient Education

Metaverse has the potential to provide the patient population virtual teaching tools on subjects such as maintaining a healthy lifestyle while preventing diseases. Additionally, they have the potential to assist the patient in gaining an understanding of the potential outcomes of their surgical procedure, as well as the extent of research conducted inside the laboratory [74]. The purpose of "preoperative patient counseling services" is to alleviate patients' anxieties by providing them with information on anesthesia, surgical procedures, and potential post-surgery issues. Additionally, these services attempt to acquaint patients with the operating environment. Virtual therapy has many benefits compared to verbal counseling. Firstly, it minimizes the impact of potential language barriers. Secondly, it reduces the time required for the doctor. Lastly, it eliminates the need for physically impaired population to leave their homes. HealthBlocks, has introduced a blockchain-powered application to aid users in engaging in physical activity and maintaining good health. Incorporating blockchain technology, Healthify has successfully created a sports and health metaverse. Digital twins (DTs) have the potential to enhance comprehension of a patient's illness by presenting digital depiction of population afflicted with the condition [75].

5.3 Medical Research

Metaverse have an application to imitate medical methods and therapies, enabling researchers in order to test and enhance novel treatments, also programs. It is particularly beneficial for treating and managing mental illnesses including ADHD, AD, and Parkinson's disease (PD), as well as conditions that impair movement, such Alzheimer's disease (AD). In the latter instance, patients were encouraged to work on both their mobility and autobiographical memory using VR therapies that took the shape of interactive games with customized training regimens. VR or Immersive rehabilitation therapy was found to enhance gait as well as balance of people with Parkinson's if utilized in tandem with traditional rehabilitation techniques and training. Clinical studies might sped up greatly with incorporating and employing

the metaverse, cutting physical and geographical borders between physicians and the patient population participating in a study researchers illustrates how adoption of the blockchain-based technologies in clinical studies and trials offers a safe, secure as well as open platform for data management. Through strengthening trust, reducing regulatory burden, and ensuring security and integrity of medical data, such a platform may support the successful and efficient execution of clinical trials [76]. Researchers will be able to use information from this medical data with less security worries if blockchain is used to improve security of E-Health Records. With the use of DTs, researchers may conduct studies without having to deal with patients directly by simulating humans and medical equipment. AI-based medicine, specifically healthcare and clinical imaging-guided diagnosis and therapy, is stated to be able to benefit from the development, testing, evaluation, control, translation, and enhancement of the healthcare metaverse, also known as "MeTAI" (medical technology and AI) [77].

5.4 Drug Development

The metaverse holds promise for speeding up the creation of novel medications, enhancing their effectiveness and safety, and cutting down on the time and expense needed to introduce them to the market. Drug makers may be able to create virtual worlds using metaverse to mimic effects of medications on human body [78]. By identifying possible safety and effectiveness concerns with novel treatments before they are evaluated in clinical studies on humans, these simulations may help researchers shorten the time and expense associated with drug development. VR is useful in drug design not only for interacting and seeing molecules, but also for interacting "on the fly" with molecular dynamics simulations (sometimes referred to as "interactive molecular dynamics in VR" or "IMD-VR") [79]. For example, drug development programs like as YASARA and UCSF ChimeraX facilitate virtual reality (VR) and allow docking, which is the virtual modeling of molecular interactions. Moreover, Narupa iMD is a form of IMD-VR software that lets users engage with instantaneously or reall-time molecular simulations and work together in a same virtual reality environment [80].

5.5 Therapy and Support

From the convenience of their own homes, patients might perform virtual reality workouts to enhance their movement and coordination. People live in rural or any isolated areas with mobility problems that make it hard for these people to go to medical institution may find this to be very helpful. Patients with chronic illnesses or mental health concerns might potentially attend virtual therapy sessions and support groups in the metaverse [81]. Those who are unable to get access to in-person help

might find a feeling of connection and camaraderie via these virtual support groups [82].

5.6 Laboratory Medicine

A medical laboratory environment may benefit from the use of some of the above-discussed applications of the metaverse, such as teaching and training, which can teach students, scientists, and technicians efficient laboratory collaboration techniques. But there are also certain uses for each of the three metaverse components that are unique to laboratories. For instance, DTs of labs and associated apparatus may be made to facilitate in-silico modeling, pre-evaluation, simulation, as well as smart manufacture of assays along with device performances [83, 84]. Digital modeling in laboratory rooms, surroundings, and processes, as well as dynamic 3D visits to virtual clinical labs, are made feasible via telepresence and virtual reality. A blockchain-based remote laboratory management system is an additional application that facilitates safe data exchange between students, personnel, and laboratory equipment. Software like BioVR facilitates VR-assisted biological data integration and visualization for bioinformatics and genomics research. Virtual reality (VR) has applications in mesoscopic rigid body modeling, multi-omics analysis, drug development, molecular modeling, and even 3D viewing of virtual cell. In bioinformatics, the blockchain is being also used, in safe transfer of DNA or RNA sequencing data [85].

6 Potential Challenges

Not to mention the social, technological, and legal obstacles, it will be crucial to carefully analyze privacy and ethical issues when using the metaverse in healthcare and medicine. Intellectual property rights breaches and integrity problems like fraud and the dissemination of misleading information are examples of ethical dilemmas [86]. The promotion of dangerous items may also be possible in a digital setting like the metaverse. Similar to social media, the metaverse requires clear moral standards to ensure that improper behavior is not accepted. Although the intrinsic characteristics of the blockchain may make hacking which results in the loss of sensitive personal information more difficult, individuals are nonetheless justified in being worried about their privacy in metaverse. Real-world privacy rules may not be applicable in virtual realm; thus, all parties involved should work together to design metaverse-compatible privacy legislation [87]. Social problems emerge when individuals substitute virtual reality for actual, face-to-face interaction with others, which results in loneliness. Furthermore, when individuals with mental health disorders begin interacting with the metaverse, they may mistake it for reality, leading to

further problems like Cyber-Syndrome. A major focus of technical concerns is guaranteeing the precision and dependability of virtual simulations. VR has to be very dependable, especially for medical applications, which frequently not feasible at the present. Additionally, VR/AR gear is still costly and might have unfavorable side effects including weariness, strain on the eyes, and impaired vision. Lastly, a lot of the issues identified previously have a regulatory component. The cyberlaws in place are not enough to address issues unique to the metaverse. In a virtual world, for instance, who has responsibility and liability? What happens if a virtual patient or an avatar commits a crime? A person may face legal repercussions if their avatar is connected to a single "real person," but what if AI is used to partially control the avatars? In order to maintain legal separation between avatars and people, it could be appropriate to provide avatars their own legal personality [88].

7 Conclusions and Outlook

The relationship between artificial intelligence (in all its manifestations) and metaverse is intricate, and different AI models are often the foundation and key elements of a creative metaverse model. The metaverse is now being heralded as the next big technology revolution that might significantly affect patient experience, doctor-patient relationships, and innovation and R&D processes. The metaverse is already undergoing a revolution, and in order to steer it in the proper path, physicians must embrace it as their own heroes. It takes time to get from different types of artificial intelligence to metaverse. The metaverse's potential appears to be vast, but further advancements are necessary to realize its full potential in the medical field. In a virtual setting, the DT (digital twin) simply represents a patient or medical gadget; in contrast, the metaverse provides a larger virtual realm with a greater variety of options. The metaverse is now used in medicine for virtual counseling, training, and medication development. Future uses for it, however, may include virtual labs, hospitals, or even a "care continuum," which is a complete healthcare system that follows patients over time as they get various levels of treatment, at home as well as in a clinic. Because it impacts numerous critical cognitive processes, including feeling as though one is in a hospital or lab, having a virtual patient body, interacting with another person's brain in a manner akin to a doctor and patient, interacting with other people's brains in a manner akin to a virtual classroom, and managing emotions during therapy, the metaverse is beneficial for the healthcare sector. To guarantee the metaverse's achievement in healthcare, there are, nonetheless, issues pertaining to ethics, privacy, and the social, technological, and regulatory spheres that need to be resolved. All things considered, the metaverse's future in healthcare seems bright, but new laws, legislation and rules tailored to the metaverse must be created to handle any possible negative aspects.

Table 1 Metaverse used in medicine and health-care

Sr. no	Metaverse used in medicine and health-care system
1	Consultations for Medicine
2	Training and Education in Medicine
3	Instruction for Patients
4	Medical Study
5	Drug Research and Development
6	Counseling and Assistance
7	Lab Medicine

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Metaverse and the Future of Work—A Higher Education Perspective

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Abstract Metaverse is a collaborative space offering numerous opportunities to explore. The Metaverse is the next big thing in digital interaction, promising to transform how we connect with other individuals and digital content. One of the main sectors that can utilize the potential of Metaverse is education. The Metaverse could unite students from across the globe in a shared virtual space, fostering collaboration and understanding across cultures. Metaverse also enhances student learning experience. Since the pandemic, students and teachers are more familiar with using and applying virtual environments for learning and teaching. The Metaverse could also integrate workforce training and education programs in a higher education organisational level. Even though Metaverse has attracted the attention of several researchers and educators, immersive experiential learning has always been questioned regarding the ability to retain and sustain students' learning for more extended periods. In the future, Metaverse holds significant promise for learners with special educational needs, offering customizable environments that can be adapted to individual learning requirements. However to unleash the full potential of Metaverse, understanding the role of regulations is also key.

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1 Introduction

The metaverse, a term that sounds like it was borrowed from a sci-fi novel, is actually closer to becoming a significant part of our reality, especially in the realms of work and education. In the simplest terms, it's a shared virtual environment. One created through the convergence of two differing realms; 1. Virtual physical reality and 2. physically persistent virtual environments, which includes all virtual worlds, augmented reality, and the internet. The metaverse is the next big thing in digital interaction, promising to transform how we connect with both other individuals and with digital content. In the Metaverse, classrooms could transcend traditional settings, allowing students to immerse themselves in historical events, explore the vastness of space, or delve deep into the structures of an atom. This boundless environment offers a canvas as vast as the imagination, where lessons are not just told but experienced [1].

The Metaverse could unite students from across the globe in a shared virtual space, fostering collaboration and understanding across cultures. Projects could see minds meld and ideas flourish in ways previously constrained by physical distances, much like distant lands coming together in a council of old to face a common foe. Access to education would no longer be a quest fraught with barriers. The Metaverse could offer a portal to quality education for anyone with internet access, breaking down walls that have traditionally separated learners from the knowledge they seek. Learning could become an adventure, with gamification elements that make education engaging and fun.

This chapter will focus on the perspectives of utilizing Metaverse and how it may be applied in a higher education (HE) setting. The chapter will detail the both benefits and challenges of Metaverse in HE while also explaining whether it would be a safe collaborative space for students and educators in the future. The teaching and learning skills that would be required to maximise the potential of Metaverse will also be discussed in the chapter. Finally, the chapter will conclude on some recommendations as to how education sector will be revolutionised using metaverse applications.

2 Metaverse—A Collaborative Space

Metaverse is a collaborative space offering numerous opportunities to explore. The term metaverse is said to be first defined around the turn of the millennium (2000) as a 'virtual universe where people would feel fully engaged with the available devices and realities' [2]. Metaverse, is a portmanteau of two words: meta and verse, with "meta" meaning "transcending" and 'verse,' being an abstraction of "universe,". The 'Metaverse' is hypothesized as a constituent part of the next generation internet. Metaverse's goal is to create space that is shared, connecting every existing virtual space through the Internet. Users are represented as digital avatars, within this virtual

space and they can communicate and collaborate in similar ways to the real physical world. However, there is still no singular definition of the Metaverse [3].

Metaverse had its first applications in gaming where computer games with virtual worlds were offered to gamers as unique experiences by gaming companies [2]. Recently marketers, and advertisers are also exploring the potential of Metaverse to engage their customers in new ways of brand innovation and awareness. Facebook rebranding to 'Meta', its CEO Mark Zuckerberg declared that he would want to "help bring the metaverse to life." Reflecting its popularity, in 2021, the internet searches for the term 'Metaverse' increased by 7200% [4]. Meta's head in matters of global affairs, envisions a world where augmented reality (AR) and virtual reality (VR) technologies reshape job training and education, making them more immersive, engaging, and effective [5].

McKinsey [4]. in their article on Metaverse identified that there are some elements in common as given below:

- Metaverse can encompass "immersive environments, often (not always), using virtual or augmented reality technology"
- Metaverse will be 'always on', meaning it can exist in real time
- Metaverse spans both the "virtual and physical worlds, as well as multiple platforms"
- "Metaverse is powered by a fully functioning virtual economy (not always) built" upon "cryptocurrency and digital goods and assets, including nonfungible tokens (NFTs)".
- Metaverse can enable "people to have virtual identities, presence and agency including peer to peer interactions, transactions, user-generated content, and world building". Hence it can be seen that metaverse is often characterized as a continuous evolution of today's internet with possibilities of vast digital worlds operating in parallel to the physical world [4].

Recent advances have let to tech and social media giants hailing metaverse as the future of the internet, it has already become the centre of attention to a broader audience. Not just in industry, metaverse as a concept has been the subject of academic research and discourse in a variety fields, from literature to art, to music and engineering, to education [2]. A virtual space offering potential for a variety of experiences of user engagement, Metaverse is continuing to gain significant attention in the recent years. Needless to say, Metaverse will have its own benefits and challenges in the field where its operational features will be explored [6]. From businesses, to technologists, from educators to students, Metaverse can be of potential to a variety of stakeholders. Some of the main stakeholders that can benefit from Metaverse is given in the figure below (Fig. 1).

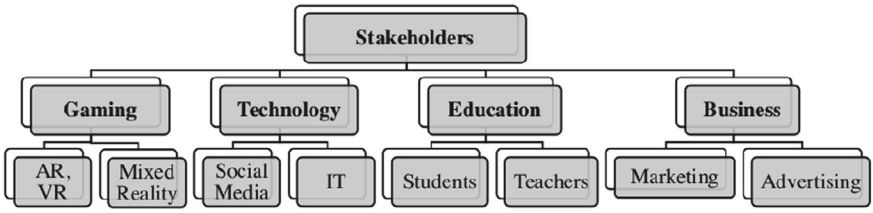

Fig. 1 Different stakeholders that can benefit from metaverse

3 Metaverse in Higher Education—Benefits and Challenges

One of the main sectors that can utilise the potential of Metaverse is education. This is because with developments in information technology, (IT), traditional education has also seen its related advancements. Metaverse can integrate a wide variety of technologies such as machine learning, game design, big data, artificial intelligence, internet of things (IoT), and Blockchain technologies. Hence it is thought that the integration and USA of Metaverse will have significant contributions towards educational development [7]. For its users including education providers, teachers and learners, Metaverse has the potential to provide a personalised and immersive learning environment and experience [6]. Since the last decade, augmented reality (AR), virtual reality (VR) and mixed reality (MR) are being used in education. However, Meta's announcement has created a new hype and the first Metaverse applications in HE have started to appear in the last few years [8].

However, it is to be noted that the metaverse is by no means a new model or paradigm in education settings as both researchers and education professionals have previously discussed its potential effects within a teaching and learning setting. As early as in 2006, Authors such as Kemp and Livingstone discussed how metaverse can be combined with the "learning management systems using a virtual world called" 'second life.' So, it is implied that educators and technology providers in the industry will continue to work together to understand the best methods of implementing quality educational practices in the classroom [9]. To help aid these applications, as with any technological intervention, understanding the benefits and challenges of utilizing Metaverse in education is of utmost importance.

By leveraging the unique capabilities of the Metaverse, educators can create tailored educational experiences that cater to the needs of different learners, including visual learners, auditory learners, kinesthetic learners, and those with special educational needs. Kinesthetic learners prefer learning by doing, moving, and touching. The Metaverse offers unparalleled opportunities for these learners through interactive simulations and hands-on activities. Using VR and AR, kinesthetics learners can perform virtual experiments, conduct fieldwork in simulated environments, or practice physical tasks in a safety conscious and controlled setting. For example, medical students could practice surgical techniques in a virtual operating room,

receiving immediate feedback on their performance. This hands-on approach not only enhances skill acquisition but also boosts confidence in practical settings [10].

3.1 Benefits

The potential benefits of integrating the metaverse within either workforce training and education programs are manifold. Imagine learning to perform heart surgery or pilot an airplane in a risk-free, virtual environment that simulates real-world challenges and scenarios. This isn't just about making learning fun; it's about enhancing skill acquisition, reducing the learning curve, and preparing individuals for the workforce in ways that traditional methods cannot match.

One of the foremost benefits Metaverse promises is that of a collaborative space for immersive, personalised and engaged learning for students and educators equally. This in turn provides increased accessibility, flexibility and interactivity for education [6]. Metaverse can potentially provide all these benefits as it is grounded in the merging of immersive technologies such as AR, VR, and mixed realities, and overarching technologies such as artificial intelligence, and blockchain, etc. Hence metaverse will also facilitate full and multisensory interaction with a virtual environment, any digital objects and people at the same time providing new opportunities for better links between the 'real' and the 'virtual world' [8].

Another notable benefit of Metaverse will be enhanced student learning experience. Since the pandemic, students and teachers are more familiar with the use and application of virtual environments for learning and teaching. In the Immersive Learning Network's 2021 report, it was reported that thinking related to extended reality (XR) and its use, has increased due to the effects of the pandemic. Massive developmental changes have occurred since 2020 and are able to confer a high level of maturity, enabling educational practitioners to holistically enhance the overall learning environment and student experience. Therefore, it is imperative that through metaverse, mixed reality environments will become integral part of our students future learning and work experience in the near future and extended beyond [11].

Jeong et al. [12] studied the use of "Metaverse education framework" in HE for a "shared learning environment". Their results found that,, in Korea, the establishment of consortium university by utilising Metaverse learning worked very well providing various advantages by creating the linkages between (local) governments, universities, and companies. The virtual campus by Metaverse opened as a part of this framework overcame distance between regions for these establishments in the consortium, and an LMS system easily enabled learning management for those participants involved in the learning and teaching in the consortium.

Even though Metaverse has attracted the attention of several researchers and educators, immersive experiential learning has always been questioned on the ability to retain and sustain the students' learning for longer times. Metaverse and such technologies brings in novelty as a benefit, for engaged learning but it is still dependent on learning motivation. Jen [13] explored changes in "growth mindset, learning

attitudes, and self-efficacy of students with different motivation levels regarding the metaverse", evaluating its use in higher education through a framework utilising both 'conceptions and perceptions'. Their findings pointed out that motivation when learning is "an important factor affecting students' growth mindsets, learning attitudes, and self-efficacy of learning with metaverse" [13].

3.2 Challenges

Student learning experience is always challenging, especially if it involves a new technology. Technological maturity is required for the uptake of metaverse in teaching and learning, therefore there will be many questions we will be addressing for its use in educational settings [7]. Virtual and augmented realities have been around for some time and its use in educational setting has been tried and tested but not to a scale where it is also connected to digital workplace in a continuous, connected, scalable manner. Hence, we can say that Meta's ambition for Metaverse is still very much a work in progress [14]. Therefore, there will be challenges related to the technical limitations of Metaverse, and not to mention the privacy and security challenges associated with it [6].

To be able to provide a safe, equitable, and sustainable platform through Metaverse is a challenge as provision of a collaborative space through Metaverse has to keep up with the regulatory standards related to user rights and upkeep the necessary data and privacy standards. The article from McKinsey [15] reiterates that building the metaverses in itself is challenging because it has to keep talent and diversity issues at check, all the while minimizing technologically based biases and ruling out the issues of misuse such as; abuse, harassment and forms of mis- or dis- information [15].

Since the pandemic, the focus on higher education teaching practice and student experience has been under scrutiny. Student expectations are continuously evolving and there is a need for Universities to be able to understand and respond to these changes, which remains a challenge. The traditional campus based merits are always compared to the online learning strategies, and the same is associated with the Metaverse. This can be challenging as virtual environments are credited with less engagement compared to the traditional classroom settings. In addition, there has been a wide recognition that the online learning experience for students, has not always been positive [11].

In the 2020s a workplace looks very different from what we would have conceived during pre-pandemic times. An increase in hybrid, and remote working patterns has drastically changed perceptions and expectations around why, how and where people choose to work. However, there is a clear pathway for Metaverse to provide a continuum for today's young generation from their academics to workplace through its platforms. As students become more familiar with the Metaverse applications, and they move to their workplace, the emergent metaverse will provide an opportunity to regain or evoke the spontaneity, freedom, interactivity, and fun of team-based

learning to maintain productivity, flexibility and convenience through using metaverse in their workplaces. With these principles as a guide, leaders can begin to reimagine and (re-)create their workplaces with a focus on the future, on the basis of the metaverse experiences their younger talent pool are familiar with [16]. However, one of the main challenges in terms of cost implications that Meta and its partners face is convincing employers and industries of the technology's value. Scepticism among employers, particularly concerning the investment in VR technology and its effectiveness, remains a significant barrier [17].

Metaverse can also offer opportunities or be a threat in education. "Metaverse will make all activities in education be carried out in a virtual world" [18]. As students readiness to the technology evolves, novel experiences of learning through metaverse will become both authentic and meaningful. The learning and teaching process has become regardless of time and space, so metaverse and related technologies are carried out in an all encompassing and more active way. Growth and advancement of the Metaverse is essential, however it cannot be used as an essence of life. Also, metaverse can be an existential threat to the (real-world) schools and institutions alongside all the undertakings that occur within them, however not all of them will all be suitable to be replaced by Metaverse. Metaverse will only be a single element or tool in the world of teaching and learning to improve education services, because metaverse and the 'educational space' aims to humanise humans and not virtualise humans. With the development of metaverse, the technology in itself can bring opportunities and threats to humans involved in education. The task for educators is to make the education and learning real. Also, it is noteworthy to say that "no technology can replace the role of teacher" [18]. Finally, issues such as a digital divide, privacy concerns, and the prescient need for substantial investment in technology and training must be addressed [19]. Moreover, the effectiveness of metaverse learning experiences must be carefully evaluated from a regulatory perspective to ensure they meet educational objectives.

The table below will provide a SWOT (Strength, Weakness, Opportunity and Threat) analysis for the utilisation of Metaverse for teaching and learning in HE (Table 1).

4 Metaverse in Higher Education—A Regulatory Perspective

Metaverse is generating changes in existing social structures through being an ever expanding virtual reality,. Hence it is important to understand how these changes will impact for universities and higher education from a regulatory perspective. Not only has it provided unique opportunities for academic excellence and growth but also challenges that will affect the degree of success of its adoption and making optimal utilisation of the available resources and capabilities. This is dependent on how education administers adopt these realities and how parallel generational challenges among

citizens and universities can adapt to the changing educational systems. If accepted with positive attitudes, and the right supportive framework, the advancements in the higher education systems, a concept termed 'Metaversity' can be a reality of the near future as an effective representation of universities in the metaverse environment. The transformation of universities into virtual worlds, therefore, definitely requires a deeper investigation into the need of regulatory frameworks on a regional basis as a support mechanism for its users [20].

The need for regulatory frameworks for applications such as metaverse is obvious. As discussed in the challenges, metaverse is still a technology to be defined and it is part of an experimental set up in the educational sector. The first need for regulations is created due to the limitations it possesses in terms of social interactions in the virtual spaces. This triggers personality changes from an individual thinking a "me as I am" to a "me I want to show" person. This is because, the individual has limits to interact and allows him/her to hide or change personality traits. In addition, this new kind of social life brings new challenges of privacy and data security related issues that are not caused in a real-life space. The other concern is the degree of freedom provided in such platforms which cannot be completely controlled by the educational administer. Researchers have already reported the exposure of young adults to new forms of crimes, harassment, or online bullying. Finally virtual spaces can create identity confusion among young people when given higher degree of immersion experiences. Screen addiction, as a reality, has been demonstrated as a concern repeatedly and should definitely be taken into account when making policies and regulations to offer education through metaverse applications. As a start for development of regulations on Metaverse, Asua et al. [21] has already underlined three points from a European regulatory perspective. Firstly, the regulations should aim at protecting its citizens and influence worldwide regulations on this matter. Secondly, as Metaverse will be a proper virtual world, extensions of already existing provisions such as GDPR and DSA are required. Finally, national and international regulators need to research and understand Metaverse to prepare and create a healthy and safe environment for all [21].

5 Metaverse in Higher Education—Skills Requirements

As metaverse is a space for collaboration, it has the potential to revolutionize preactical training and skill development. In addition, Metaverse can significantly reduce the time and physical space needed to develop the existing, and acquire new skillsets. Harvard Business Review reports that as metaverse has its "deep roots in gaming", Metaverse can tap into "the potential of gamified learning technologies for easier and faster skills acquisition". The solutions for skills development offered by metaverse can include AI enabled digital coaches, virtual reality role-play exercises and simulations enabled with worker avatars, and other immersive quest based games and methods. Learning by doing is facilitated through Metaverse as AI powered bots can assist when learners get stuck, provide nudges, and set scaled challenges. As

visually demonstrating concepts such as engineering design can be better enabled in virtual world training, this has clearly a greater advantage over traditional instructor or classroom based training. There are companies such as Bosch, and Ford already using a VR-training tool, using the Oculus Quest headset, to train technicians on electric vehicle maintenance [16].

Metaverse enhances skills training as it can assist both teachers and professors in experiencing teaching and learning in new ways with the associated technologies [21]. Higher education institutions (HEIs), since COVID has already understood that technology enhanced learning has an important role in providing learning skills to their students and teachers. HEIs are now trying to provide high quality online education through their VLE platforms rather than treat them as resource repositories. Metaverse will enable better scaffolding, communication, relationship building and with the ease of access to wider learning resources and technologies [22].

Forbes reports that, companies can utilise Metaverse to train employees remotely offering 'hands on' learning in their own comforts. Metaverse is able to provide real time feedback between different teams on projects which in turn allows time savings and cost reduction on skills training. Prior to Covid, only 20% of people worked from home, but during the pandemic that number increased to 70%, and even as COVID ended, 54% of people expressed their preference to continue working from home. With this trend still ongoing, metaverse can enable training and development opportunities for those who opt to work from home in comparison to the people who work from office settings. Therefore, through clear communication, company processes, and infrastructure, today's team can produce results even remotely with the help of Metaverse. Hence Metaverse can offer help by encouraging collaboration and demonstrating what is needed through action instead of words [23].

6 Metaverse in Higher Education—Future Prospects

Today's Gen Z students are tomorrow's consumers. They are more familiar with virtual worlds, transactions, and goods than millennials or even their previous generations tend to be [15]. This generation has gone through virtual education at the time of COVID and have experienced its benefits and challenges equally. Nevertheless, technology currently leads the way in changing 21st century education, whether it's university-based programmes, acquiring real-world skills, or the teaching and learning of concepts taught in both schools and universities.

More studies are now researching the efficiency of metaverse technologies in institutions and whether such applications can help students learn and be more motivated [9, 24]. There is research which are investigating whether ChatGPT as an AI tool can be included in metaverse education and has concluded that it must be included to situate learners in realistic, problem-solving, and creative ways of thinking [25]. Another research delved into the intricate landscape of metaverse using technology acceptance model and it found that policies and regulations play a significant role in metaverse adoption in a country which needs to be considered for long term [26].

Table 1 SWOT analysis of students and teachers' utilisation of metaverse

Strengths	Weaknesses
• Student engagement • Enhanced student experience • Flexibility; real time immersion • Adaptability in different virtual environments and realities • Interactivity and convenience Collaboration	• Student motivation • Data privacy and Security • Potential for abuse, harassment, and misinformation cases • Student expectations • Generational challenges
Opportunities	Threats
• Continuum to new and hybrid workplace of the future • Digital skills development	• Regulations • Laws and Policies

Nevertheless, more understanding is required as to reflect the impact of elements of curriculum design and student engagement in learning and teaching if new medium such as Metaverse is used in higher education in the near future. A clear knowledge of the education goals, selecting the right supporting tools and technologies, and provision of training and support for both educators and students are essential before unlocking the full potential of a platform such as Metaverse [6].

In the future, Metaverse holds significant promise for learners with special educational needs, offering customizable environments that can be adapted to individual learning requirements. For students with autism, for example, the Metaverse can provide controlled social environments for practicing communication and social skills without the overwhelm of real-world interactions. Similarly, learners with physical disabilities can engage in virtual field trips and experiences that might be inaccessible to them in the physical world. Moreover, educational content in the Metaverse can be designed with accessibility in mind, incorporating text-to-speech, closed captioning, and other assistive technologies to ensure all learners have equal access to information [27].

McKinsey article notes that as a long-term potential of the metaverse may generate up to $5 trillion by 2030 across consumer and enterprise use cases [15]. The transformative power enabled by Metaverse will empower educators as they will not just be 'transmitters' of information, but more of architects and story tellers in virtual realms. Therefore, metaverse unfolds itself as an 'expansive canvas' where educational experiences will captivate, challenge and inspire learners [28]. Even though metaverse hails more collaborative opportunities in a virtual world, it has never been more important to stress about social relationships and emotional expression, bonding, touch, smell, and body language as they are critical forms of communication which should be tried to be preserved in virtual environments [29].

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Exploring the Potential of Metaverse-Driven Intelligence Systems in Virtual Healthcare Realms

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Abstract The Metaverse represents a new frontier where users can connect, create, and explore in unprecedented ways. As this virtual realm expands, its influence extends beyond entertainment and into sectors like healthcare, where its immersive capabilities hold the promise of transforming patient care and medical practices. In the dynamic landscape of healthcare, the metaverse emerges as a transformative force, poised to revolutionize the delivery of medical services. The first section of the research introduces the idea of the metaverse and how it relates to healthcare. It then goes over the several ways that VR technology is used in healthcare, including telemedicine, medical education, and therapeutic interventions. The study delves particularly into the use of virtual reality (VR) technology. Through meticulous analysis, it explores the diverse applications of virtual environments within the metaverse, spanning patient care, and also looks at how virtual worlds are used in medical training and education, highlighting the immersive learning experiences that VR simulations offer medical professionals. From enabling remote patient monitoring to providing immersive learning experiences, the study elucidates the myriad ways in which VR is reshaping healthcare practices. Ethical considerations and security challenges inherent in this paradigm shift are thoroughly examined, emphasizing the imperative for deliberate implementation and ongoing research. Ultimately, underscoring the potential of the metaverse to enhance healthcare accessibility and outcomes, while acknowledging the necessity of navigating its complexities with caution and vigilance.

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1 Introduction to Metaverse-Driven Healthcare Intelligence

The metaverse technology integrated with healthcare helps create a new space for everyone where various medical services can be provided to different people remotely. It creates an active digital environment in which associates can work together and analyze how these virtual healthcare services are delivered to different people [2]. This concept of the metaverse helps overcome many limitations, like physical boundaries, and allows medical professionals, and even for researchers to interact and access different types of medical services and information. The metaverse creates a medical environment that is similar to the realistic scenarios. It helps the consumers feel real and truly involved. This technology helps both the medical professionals and the patients to communicate effectively, analyze the problems of the particular patient, and provide a feasible solution. Patients can schedule virtual sessions, learn more about their health conditions and the necessary precautions, and contact doctors for support [1].

Doctors can use this virtual technology for recommendations and training. Healthcare in the metaverse helps in customizing the preferences of an individual to suit their needs. Preferences such as their culture, language, and other aspects are considered to make each person using the platform feel included. This helps the patients to ease their activity with the platform. The new technologies make this virtual space interactive and suggest more realistic suggestions. This virtual world is all about making healthcare easier to access, improving how doctors and patients interact with each other, and ultimately making sure everyone gets better care.

The traditional handwritten paper records that were used earlier have now transitioned to high level digital ecosystems that support the need of the modern age. The complexities that arised due to the usage of manual record on paper charts that are stored and organized in the enormous cabinets have promoted the adoption of electronic health records and healthcare information technology to smooth the data management and improve efficiency in healthcare [8]. The transitional shift to EHRS in medical data management enables effortlessly accessing the information, securely storing the data and smooth exchange of information across healthcare facilities by digitalizing the patient record.

The EHR system initially focused mainly on capturing and storing patient data thereby creating a strong framework that allows the different medical institutions to effectively and smoothly communicate and exchange important data, which in turn promotes the collaboration and improvement of overall quality of medical services. With the new technologies and changes in regulations, more developed HIS systems have come into existence. his new technology offers a wide range of functions and supports different medical workflows, administrative tasks, and decision-making processes.

1.1 Convergence of the Metaverse and Healthcare Intelligence

The merging of the metaverse and health care knowledge stands for an advanced blend of electronic worlds plus healthcare development, introducing a brand-new age of transformative possibilities for the healthcare market. At its core, this convergence involves the assimilation of immersive digital settings, sophisticated innovations, and data-driven knowledge to change medical care distribution, individual treatment, medical research studies, as well as education and learning.

- **Immersive Virtual Environments**: The metaverse provides a vibrant system for developing immersive digital settings that imitate real-world healthcare setups, making it possible for individuals to participate in realistic communications as well as experiences. With digital truth (Virtual Reality), increased fact (AR), as well as combined truth (MR) modern technologies, healthcare experts, people, and also stakeholders can browse online clinical centers take part in simulations as well as participate in participating tasks no matter geographic restrictions [18].
- **Sophisticated Technologies**: The merging of the metaverse and also medical care knowledge leverages a myriad of innovative modern technologies to improve health care results. Expert system (AI) and also artificial intelligence (ML) formulas power anticipating analytics, medical choice assistance systems, as well as tailored therapy suggestions, allowing aggressive plus data-driven health care treatments. In addition, blockchain modern technology makes sure the safety, honesty as well as interoperability of wellness information in online settings, cultivating trust fund and openness [20].
- **Data-Driven Intelligence**: Central to the merging of the metaverse and health care knowledge is the use of data-driven knowledge to drive actionable understandings and educated decision-making. By using substantial quantities of health care information produced from digital wellness documents (EHRs), wearable gadgets, clinical imaging plus genomic sequencing health care companies can open beneficial understandings right into person populaces, illness, therapy effectiveness, plus health care results.

The combination of the metaverse and healthcare expertise has enormous potential for altering the healthcare sector. By creating immersive virtual environments and employing modern technology and data-driven information, this integration enables healthcare stakeholders to cooperate, innovate, and provide patient-centered care in unprecedent ways [12]. As the healthcare market takes up digital transformation, the combination of the metaverse and healthcare intelligence has the potential to reinvent healthcare delivery, improving the well-being of individuals and communities globally. Healthcare information systems (HIS) are likely to continue to evolve because of technological breakthroughs, increasing healthcare needs, and changing regulatory environments.

2 Theoretical Foundations for Healthcare Intelligence in the Metaverse

The introduction of healthcare intelligence in the metaverse form presents a new play to provide better healthcare services, train medical students, and conduct research. Increased use of Metaverse frameworks enhances the healthcare domain since it supports simulation models specifically designed for healthcare simulation frameworks that provide simulation environments that are safe to practice based on real-life clinical settings, improved telemedicine frameworks that allow healthcare consultation and remote patient evaluation and monitoring, enhancing patients' accessibility to healthcare services [15]. The virtual settings include virtual waiting areas, consultation rooms, and examination areas, which improves the convenience and interaction of virtual healthcare facilities. There are several software and applications through which educational institutions provide anatomy models and simulations that help in learning as well as getting a practical feel of things.

The Intensity of Information Systems in healthcare, IIS models all focus on the use of data and information in decision making processes. Despite its potential for translating analysis into powerful prediction models, the use of statistical and machine learning techniques in the predictive analytics model is limited to the prediction of future events that may include disease forecast and allocation of resources. Clinical Decision Support Systems (CDSS) utilizes knowledge resources to guide clinicians in diagnosis, causality, and treatment by providing timely suggestions and alerts. A population health management models involves a focus of health, healthcare, and population health across the entire persons to need coverage involving healthcare disparities with population health interventions [14]. Heath informatics frameworks involve handling and processing of health information for the provision of timely and efficient health care services through well-coordinated clinical and administrative solutions with check on the quality, privacy and security of the information.

As depicted in Table 1, different frames and uses of the metaverse have been highlighted as supporting functions in healthcare, teaching, and learning. All the frameworks utilize modern technologies and incorporate data analytics to enhance various sectors of medicine. Examples include use in the design of virtual training simulation where the actual surgical procedures are simulated, the use of telemedicine where check-ups can be done at a distance, and the use of predictive analysis where high-risk patients are identified. All of these applications' goals are to enhance effectiveness in clinical routines, communication with patients, the degree of decision-making precision, and general wellness.

Table 1 Frameworks and examples of healthcare technology integration and improvement rates

Framework	Description	Example usage	Improvement rate (%)
Simulation and training environments	Virtual settings that replicate real-world clinical scenarios for training purposes	Surgical simulations	30
Telemedicine frameworks	Virtual consultations and remote patient monitoring through video conferencing and digital health monitoring	Remote check-ups	25
Virtual healthcare facilities	Immersive environments providing virtual waiting rooms, consultation rooms, and examination areas	Online consultations	20
Educational platforms	Interactive anatomy models, medical simulations, and educational resources in virtual settings	Virtual anatomy labs	35
Predictive analytics models	Use of statistical and machine learning techniques to predict future healthcare events or outcomes	Risk stratification	40
Clinical decision support systems (CDSS)	Electronic tools providing evidence-based recommendations and alerts for clinical decision-making	Medication alerts	45
Population health management models	Strategies for improving health outcomes of populations through data-driven interventions	Preventive care programs	50
Health informatics frameworks	Structured approach to managing and analyzing healthcare data for clinical and administrative decision-making	Data management	30

3 Integration of Theoretical Frameworks for Healthcare Intelligence in the Metaverse

The combination of academic structures for health care knowledge in the metaverse stands for a visionary method to leveraging well-known concepts along with techniques within digital settings to improve medical care distribution, research study, as well as education and learning [5]. By including academic frameworks from medical treatment information, clinical research study information, electronic truths plus person computer system interaction medical care companies can produce brand-new potential customers for data-driven understanding, immersive experiences together with collective improvement within the metaverse. Healthcare information structures offer an orderly technique to handling and also assessing healthcare information to sustain clinical decision-making, populace wellness tracking, along with health and

wellness system procedures [4]. These structures incorporate methods, criteria as well as finest techniques for information collection, storage space, access, evaluation, and also visualization together with for making sure information top quality, personal privacy, as well as safety and security.

By including medical care information structures right into the metaverse, medical care companies can take advantage of existing information frameworks and analysis capacities to get a working understandable model with noticeable decision-making within virtual atmospheres. Data scientific research as well as analytics designs include a range of analytical, artificial intelligence, as well as anticipating modeling strategies for evaluating medical care information and obtaining workable understandings [22]. These versions can be related to numerous medical care domain names, consisting of professional choice assistance, anticipating analytics, populace wellness monitoring, along with individualized medication. By incorporating information scientific research and also analytics designs right into the metaverse, medical care companies can take advantage of innovative information analytics abilities to obtain understandings from online individual communications, mimic healthcare situations, along with enhance professional operations within immersive digital atmospheres [6].

Virtual truth (VR) plus human–computer communication (HCI) concepts offer a structure for developing fully integrated with easy-to-use online experiences within the metaverse. These concepts include the plans for producing sensible online settings, making user-friendly interfaces, and also boosting individual interaction and communication within online rooms [22]. By incorporating VR as well as HCI concepts right into medical care applications within the metaverse, medical care companies can produce immersive training simulations, online person experiences and collective research study settings that improve discovery, decision-making and cooperation amongst health care h care experts. Ethical as well as lawful structures supply levels plus laws for making sure the accountable and moral use of medical care information, securing the privacy of the individuals and privacy together with abiding by regulative needs within online atmospheres.

By incorporating moral plus lawful structures right into the style and also the growth of medical care applications within the metaverse, healthcare companies can guarantee that digital communications, as well as information handling techniques, comply with well-established moral concepts and lawful requirements, cultivating depend on, openness as well as responsibility in online health care setups [7]. The assimilation of theoretical structures for medical care knowledge in the metaverse provides an all-natural technique to leveraging recognized concepts as well as techniques within digital settings to improve health care shipment, study, plus education and learning. By incorporating medical care informatics structures, information scientific research as well as analytics versions, digital fact coupled with human–computer communication concepts, and also moral and also lawful structures, medical care companies can open brand-new chances for data-driven knowledge, immersive experiences, as well as collective technology within the metaverse [8].

Table 2 Theoretical frameworks in healthcare technology Integration

Theoretical framework	Description	Applications
Healthcare informatics	Organized approach to managing healthcare data for clinical decision-making, population health monitoring, and health system operations. Includes data collection, storage, analysis, visualization, and ensuring data quality and security	Clinical decision support, population health information exchange, electronic health records
Data science and analytics	Statistical, machine learning, and predictive modeling techniques for analyzing healthcare data and deriving actionable insights. Applicable to clinical decision support, predictive analytics, and personalized medicine	Clinical decision support systems, predictive analytics platforms, population health management tools
Virtual reality and HCI	Framework for creating immersive virtual experiences. Involves designing realistic virtual environments, intuitive interfaces, and enhancing user interaction. Applicable to medical training simulations, virtual patient experiences	Medical training simulations, virtual patient experiences, collaborative research environments
Ethical and legal frameworks	Guidelines and regulations ensuring ethical use of healthcare data and compliance with regulations in virtual environments. Ensures patient privacy, data security, and compliance with healthcare regulations	Protecting patient confidentiality, ensuring secure data handling, compliance with healthcare regulations

As shown in Table 2 the theoretical structures that could be employed when incorporating HI into a metaverse are depicted. Several of these frameworks encompass data input, processing, visualization, virtual and augmented reality, as well as ethical implications. To further explain the strategies of each framework, there is a specific process in utilizing sophisticated technology and methodological approaches to improve health care delivery, decision-making, and patient care in the virtual environment.

4 Technological Enablers and Applications for Healthcare Metaverse Integration

To make healthcare a part of the metaverse, technology in the form of Virtual Reality (VR) and Augmented Reality (AR) needs to be incorporated. VR brings individuals into interactive environments, thus making it possible to get virtual consultations, practice for physicians, and even have simulations [19]. AR integration puts digital information on top of the physical environment and is used in facilitating learning through valuable engagements. AI and ML denote the integration of artificial intelligence and machine learning into analyzing and interpreting healthcare data that

help in decision making and creating a personalized approach to patient care. Data analytics and predictive modeling make additional improvements in medical decision outcomes by analyzing data transcripts and determining resource allocation [13].

These technological enablers allow for smooth interactions between care providers, hence introducing effective and efficient integrated care delivery models in different centers. Organizational and multimedia technologies like video teleconferencing systems and software advance interdisciplinary cohesiveness and advance patient care. Also, security and privacy technologies prevent fraud, unauthorized access, and other practices that compromise the confidentiality, integrity, and availability of health information in the electronic platforms. The integration of blockchain technology facilitates trust, promotes data integration, and conveys adherence to regulatory frameworks in digital contexts for healthcare services [15].

Augment reality and virtual reality indeed work wonders when it comes to healthcare delivery since a patient gets an actual feel of what they are going through. Simulations in medical training remain essential for evocations of practices, operations and emergencies in the training of students as well as for staff development. The areas of application of virtual reality in the field of clinical medicine include the use of VR-based models for planning the surgical interventions and for better understanding the 3D structure of the patient's anatomy, which seems to help the surgeons to achieve a higher level of accuracy in the operations performed and, therefore, promote the overall improvement of patients' outcomes [3].

As represented in Table 3 these technologies also have a significant role in a patient's pain and therapy, which involves the intensification of feelings, as a way of reducing the pain and stress during certain treatments or therapies. In the context of patient awareness and involvement, particularly using technologies such as VR and AR, this is a plus since patients can simulate or better still be exposed to various medical conditions, treatments or procedures. It also enables the patients to start learning about themselves virtually in three dimensions, to understand about their illnesses and the steps which can be taken regarding their treatment and to get aids concerning their health information [11].

As shown in graph 1 the growth rates of various technologies within the healthcare sector is presented. The data encompasses five key technological categories: Blockchain Technology, Virtual Reality, Augmented Reality, Artificial Intelligence, and Predictive Analysis. Predictive Analysis leads with a growth rate of 40%,

Table 3 Overview of applications of metaverse enabling technologies

Technology	Application
Virtual reality	Medical training, surgical planning [19]
Augmented reality	Real-time guidance during procedures
Artificial intelligence	Data analysis, decision support
Data analytics	Historical data analysis, predictive modeling
Communication	Seamless collaboration among healthcare professionals
Security and privacy	Ensuring integrity and privacy of healthcare data

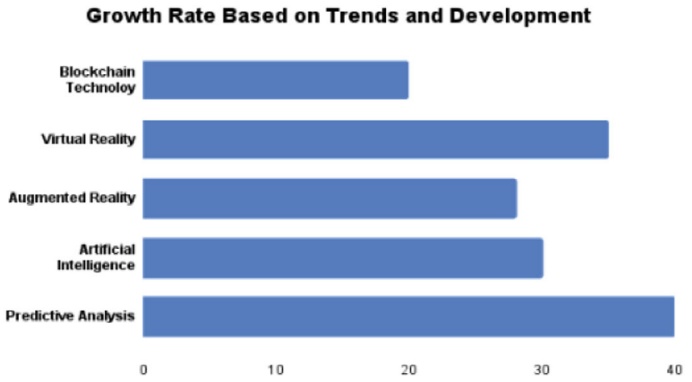

Fig. 1 Growth rate of various technologies in healthcare

followed by Virtual Reality at 35%, and Artificial Intelligence at 30%. Augmented Reality shows a growth rate of 28%, while Blockchain Technology, although growing, has the lowest rate at 20%. This comparison highlights the rapid adoption and expansion of advanced technologies in healthcare, emphasizing the significant impact of Predictive Analysis and Virtual Reality in driving innovation and improving patient care (Fig. 1).

4.1 Artificial Intelligence and Machine Learning for Healthcare Data Analytics

Expert System along with Artificial Intelligence are driving a transformative shift in healthcare information analytics, encouraging companies to take advantage of the wide range of information at their disposal for transformative understandings as well as results [1]. Essentially these modern technologies change just how health care information is refined analyzed as well as used to maximize treatment distribution, professional decision-making, together with person end results. At the core of their effect exists the ability to enhance information handling as well as administration [9]. With innovative formulas, AI together with ML automate the removal, purifying as well as normalization of health care information making certain its high quality along with uniformity for evaluation. This fundamental capacity lays the structure for a wide range of applications throughout the health care landscape. Anticipating analytics attracts attention as a characteristic application, where AI and also ML designs take advantage of historic information to anticipate future occasions or end results. From anticipating client readmissions together with illness development to maximizing source use these versions encourage medical care companies to proactively step in eventually boosting person results as well as functional effectiveness.

In tandem, AI-powered Clinical Decision Support Systems (CDSS) offer important understandings to healthcare specialists at the point of treatment [8]. By examining individual information as well as medical standards, these systems use evidence-based suggestions maximizing medical diagnosis therapy preparation as well as medicine administration. Tailored medication arises as an additional frontier with AI as well as ML making it possible for customized health care treatments based upon specific person features. By examining personal information, consisting of hereditary info plus therapy reactions, these modern technologies lead the way for accuracy medication, enhancing therapy end results as well as decreasing negative responses. In addition, AI as well as ML play a critical duty in populace health and wellness administration, by examining huge datasets to determine at-risk person populaces, screen condition patterns and also establish targeted treatments. This ability allows healthcare companies to concentrate on treatments and also ration sources successfully, advertising preventative treatment coupled with boosting general populace health and wellness [17].

5 Applications in Healthcare Delivery and Patient Care

5.1 Telemedicine and Virtual Consultations

Telemedicine and also online examinations stand for a critical application of metaverse-driven healthcare knowledge making it possible for remote accessibility to health care solutions and also appointments via immersive online settings [1]. This area discovers just how the combination of telemedicine within the metaverse changes client treatment shipment, helps with accessibility to specialized health care competence as well as improves patient-provider interaction. With online examinations, individuals can get in touch with doctors in real-time, no matter geographical obstacles, leveraging modern technologies such as video clip conferencing, digital characters and also interactive user interfaces [13]. These online experiences imitate typical face-to-face examinations enabling doctors to perform evaluations, go over therapy choices, give clinical suggestions in a safe and secure and practical method. In addition, telemedicine systems within the metaverse deal extra performances past traditional telehealth options, such as online waiting areas, interactive wellness analyses together with immersive person education and learning components. These functions improve the general individual experience plus interaction promoting a feeling of existence and also cooperation between clients as well as suppliers.

Furthermore, online examinations allow doctors to expand their reach to underserved or remote populaces, address medical care variations, and boost medical care accessibility for people with movement restrictions or transport obstacles [16]. By leveraging the metaverse for telemedicine, healthcare companies can enhance source application lower health care prices together with boost person results. By welcoming these advancements, medical care companies can progress in the direction of extra

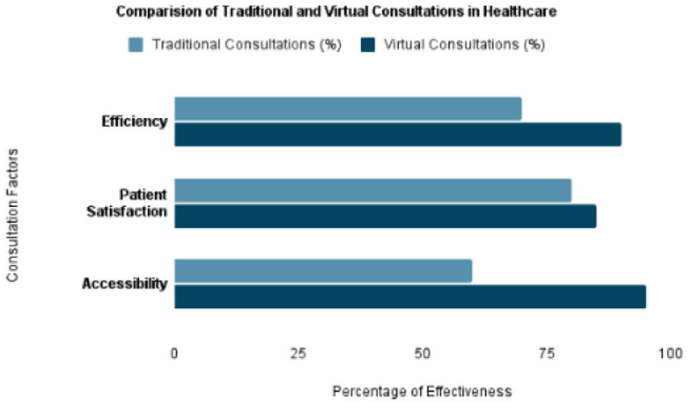

Fig. 2 Comparison of traditional and virtual consultations in healthcare

patient-centric easily accessible, as well as effective designs of treatment shipment [5].

As depicted in graph 2 the intention of using traditional consultations and virtual consultations in healthcare. The data highlights three key metrics: There are always advantages of Decentralized Administrative Structures as Cost efficiency, patient satisfaction, and accessibility. When patients interact with a virtual consultant 10% higher efficiency is observed as compared to 70% for the normal consultant. There is also a small improvement in patient satisfaction, virtual consultations receiving 85% satisfaction rating while normal methods receive 80%. As illustrated by the results above, there is a higher percentage of virtual consultation and therefore accessibility is improved. Comparing the two, it is clear why virtual consults should be implemented as part of health facility care models since they can enhance service provision and client experiences (Fig. 2).

5.2 Virtual Training and Simulation for Healthcare Professionals

With digital training and also simulation healthcare experts can participate in reasonable, hands-on knowing experiences that duplicate medical situations, treatments along with person communications. These digital atmospheres take advantage of modern technologies such as digital fact (VR) plus increased fact (AR) to produce realistic simulations of clinical treatments, medical treatments and also client treatment circumstances. In addition, online training and also simulation systems within the metaverse provide a risk-free coupled with regulated atmosphere for doctor to exercise as well as fine-tune their medical abilities without danger to individuals [17]. These systems integrate responsive comments, activity monitoring and also

interactive simulations to supply sensible comments as well as analyses, making it possible for students to establish effectiveness and also self-confidence in different scientific situations. Furthermore, online training together with simulation encourages doctors to gain access to specialized training components plus instructional sources customized to their discovering requirements as well as job objectives.

These systems provide adaptability in educating distribution, enabling students to participate in self-paced knowing components collective simulations or instructor-led training sessions based upon their choices together with discovering goals. Additionally, the assimilation of digital training as well as simulation with health care knowledge systems in the metaverse promotes data-driven understanding analytics, efficiency evaluations as well as skills monitoring [3]. These understandings allow teachers plus training managers to keep an eye on student development, recognize locations for renovation as well as customize discovering experiences to enhance academic results [8]. Generally online training plus simulation for doctor within the metaverse stand for a transformative strategy to clinical education and learning as well as training, leveraging immersive modern technologies to boost understanding performance advertise scientific skills as well as boost individual safety.

5.3 Remote Patient Monitoring in Virtual Environments

Remote person tracking in digital settings stands for a sophisticated application of metaverse-driven health care knowledge, making it possible for continual tracking as well as administration of individual health from another location via immersive electronic systems [10]. This area discovers exactly how the combination of remote client surveillance within the metaverse changes health care distribution, promotes aggressive treatments, plus boosts individual results [6]. With online atmospheres doctor can from another location keep track of clients' essential indications, physical specifications, as well as wellness actions in real-time, leveraging wearable gadgets, sensing units, coupled with Internet of Things (IoT) modern technologies. These online tracking systems supply a smooth and inconspicuous means to gather and send client information allowing doctors to track individuals' health and wellness standing and step in quickly in situation of irregularities or deteriorations [20]. In addition, online atmospheres offer a vibrant and interactive system for clients to participate in self-monitoring, health and wellness monitoring, coupled with attachment to therapy strategies. Individuals can access customized wellness control panels, obtain real-time comments on their health and wellness metrics, and join digital assistance teams or mentoring sessions, promoting a feeling of empowerment and responsibility in handling their wellness [3].

Furthermore, digital settings promote remote appointments as well as follow-up visits between people as well as doctors, getting rid of the requirement for in-person goes to as well as decreasing healthcare-related traveling and prices [24]. Individuals can connect with doctors with online characters, video clip conferencing or telepresence modern technologies allowing customized treatment distribution together

with connection of treatment in digital setups. Additionally, the combination of remote client tracking coupled with medical care knowledge systems in the metaverse allows data-driven understandings, anticipating analytics plus individualized treatments based upon person health and wellness information [9]. Medical care carriers can take advantage of artificial intelligence formulas to assess fads, recognize threat elements and also forecast unfavorable occasions permitting aggressive treatments as well as precautionary treatment methods. Generally, remote person tracking in online atmospheres within the metaverse stands for a transformative technique to healthcare shipment that takes advantage of immersive modern technologies to improve person interaction, enhance medical results as well as maximize source use [10]. By accepting these advancements, can prolong treatment past conventional professional setups.

As shown in Fig. 3 a clear understanding of the annual adoption and implementation of health technologies and the improvement rates they brought about each year from 2010 to 2020. From the data, it depicts that the adoption rate has risen gradually over time getting to 60% by the end of 2020 from the initial 10% in the beginning of 2010. Similarly, the patients' outcomes increased due to the growth of the improvement rates in the years that followed and amounted to 30% in 2010 and 80% in 2020, accordingly. Hypothesis 2 posited that there would be a significant positive correlation between technology adoption and patient outcome, and the data analysis results support this hypothesis, indicating the importance of advancing technologies in optimizing patient experience and health system performance throughout the decade.

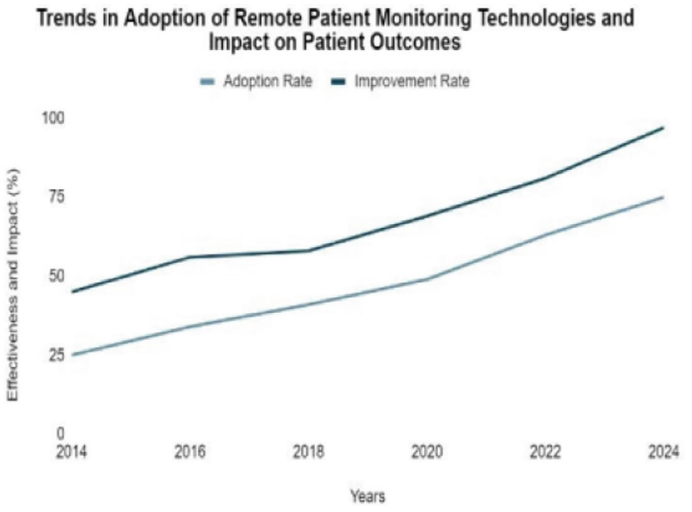

Fig. 3 Trends in adoption of remote patient monitoring technologies and impact on patient outcomes

6 Advancements in Medical Research and Development

6.1 Synergies in Metaverse-Enabled Medical Research: Virtual Laboratories and Collaborative Platforms

Medicine exploration as well as medical tests performed in digital research laboratories stand for a cutting-edge application of metaverse-driven medical care knowledge. These digital atmospheres increase pharmaceutical advancement as well as screening by leveraging innovative computational designs, molecular simulations, and also expert system formulas to anticipate medication efficiency as well as maximize prospect homes. In addition digital research laboratories help with partnership amongst scientists plus drug business using common data sources, collective devices plus online work areas for tip exchange plus speculative style. Furthermore, they allow remote employment, authorization, evaluation Tracking of professional test individuals via immersive user interfaces improving interaction together with retention [11]. Incorporated with medical care knowledge systems digital research laboratories make it possible for data-driven understandings together with tailored medication methods maximizing test layouts as well as therapy results [12]. Collaborative study systems in the metaverse promote interdisciplinary partnership and also understanding sharing amongst scientists, offering digital workspaces with interaction devices, job monitoring functions plus academic sources.

These systems help with real-time partnership, improve process as well as advertise networking plus specialist growth within digital study neighborhoods. Incorporated with medical care knowledge systems collective study systems make it possible for multidisciplinary cooperations coupled with data-driven understandings throughout medical care domain names, speeding up clinical development as well as advancement explorations [16] (Table 4).

Table 4 Stages of drug development process in healthcare

Stage	Activities
Target identification	Define the target based on disease diagnosis, conduct a literature review, and validate target relevance and the kind of drugs that work
Hit identification	Perform virtual compound screening of different modules, utilize molecular docking, know the lead compounds
Lead identification	Conduct the molecular modeling, refine lead compounds, predict pharmacokinetic properties
Preclinical testing	Evaluate lead compounds in vitro, assess ADME properties, and conduct toxicity studies
Clinical trials	Initiate Phase I trials, progress to Phase II for efficacy, conduct Phase III for confirmation

6.2 Patient-Centric Research Initiatives Enabled by Metaverse Technologies.

Patient-centric study efforts made it possible for metaverse innovations to signify a pioneering method to research techniques, putting clients at the leading edge of clinical questions as well as advancement. This area discovers just how the assimilation of metaverse innovations helps with the co-creation of study ventures with clients, improves individual involvement and also nurtures addition together with empowerment in the research study procedure. At the core of patient-centric study efforts in the metaverse is the principle of participatory research study where individuals proactively add to the style, application, plus variation of research study research studies [18]. Via immersive digital settings, individuals can participate in collective study tasks offer input on study concerns as well as share their lived experiences and also viewpoints with scientists plus other individuals. In addition, metaverse modern technologies use cutting-edge devices and also systems for client interaction together with information collection, making it possible for individuals to take part in research study research from another location as well as by themselves terms.

Individuals can access online research study websites, full studies plus take part in online emphasis teams or co-design sessions, promoting significant involvement along with cooperation throughout the research procedure. Additionally patient-centric study efforts in the metaverse advertise openness, depend on, coupled with responsibility in research study methods by supplying people with accessibility to study searching for, information understandings as well as chances for comments as well as discussion [21]. Online study neighborhoods as well as assistance networks provide clients a system to get in touch with peers share experiences, along with advocate for research study top priorities that straighten with their requirements plus choices. Furthermore, the combination of patient-generated wellness information (PGHD) and also patient-reported end results (PROs) within online research study systems allows scientists to record abundant, real-world information that shows individuals' everyday experiences along with obstacles.

By integrating PGHD plus PROs right into study research studies, scientists can get understandings right into person choices, therapy actions, as well as lifestyle end results, notifying a lot more patient centered as well as individualized methods to health care research study and shipment [14]. Overall, patient-centric study efforts made it possible for by metaverse modern technologies stand for an advanced standard change in study approaches encouraging people as energetic companions in the study procedure as well as promoting partnership, inclusivity as well as patient-centeredness in clinical query coupled with technology. By welcoming these campaigns, scientists can take advantage of the cumulative knowledge along with experiences of people to drive purposeful advancements in health care study as well as enhance individual results [15].

7 Addressing Security and Privacy Challenges and Future Directions in Healthcare Metaverse Intelligence

Certain perspectives on security and privacy must be provided to maintain the data integrity and apply ethical motivations in the medical metaverse. This entails the use of big encryption, security features to be put in place so that virtual health records cannot be easily accessed without the right permission and storage system. Encryption for instance, helps to maintain privacy especially when transferring or storing important patient data while access control helps to restrict the amount of information which can be accessed by the wrong entities. There are some other measures that can be taken for the better protection of data and these are data partition and storage as well as data encryption. Less expensive than the use of tokens and smart cards, strong passwords, multi-factor authentication, and biometrics enable reliable authentication of users and keep out intruders. Having stringent passwords and other authentication measures as well as checking on these regularly can greatly minimize the threat of identity theft and hacking into the cyber space healthcare facilities.

Ethical Considerations and Privacy Safeguards:

- Ethical considerations and privacy safeguards are vital in medical metaverse applications to protect patient autonomy, confidentiality, and privacy [8].
- Healthcare organizations must adhere to ethical principles, such as respect for patient autonomy and informed consent, when collecting, storing, and sharing patient data within virtual environments.
- Implementing privacy-enhancing technologies such as differential privacy and data anonymization techniques can help mitigate privacy risks and protect patient confidentiality in medical metaverse applications [2].
- Furthermore, healthcare organizations should establish clear policies and procedures for data handling, breach notification, and patient consent to ensure compliance with ethical standards and regulatory requirements.

As depicted in Table 5, the interplay between data protection, security, ethical considerations, and virtual health records (VHRs) underscores the foundational aspects of healthcare data management. With policies like HIPAA in the USA and cybersecurity measures, alongside ethical guidelines and VHR policies, the aim is to ensure patient privacy, data integrity, and secure information transmission. This concise overview highlights the essential components essential for navigating the complexities of healthcare data responsibly.

The implementation of personalized medicine and optimal therapy in the concept of the medical metaverse is a major step in the advancement of clinicals, where designs based upon a patient's individuality and needs can be recommended. Lack of complete patient information ultimately helps the clinicians to find out ideal treatment

Table 5 Properties, policy implications, and regulatory frameworks in healthcare data management

Properties	Policy implications	Regulatory frameworks
Data protection	Following the rules and keeping the privacy of information	HIPAA(USA)
Security	Make sure that the storage and transmission of information is done securely	Cybersecurity
Ethical considerations	Respecting patient's right to have privacy	Guidelines that promote ethical practices
Virtual health records	Controls the access to the information and promotes the data integrity	VHR policies

plan based on the rendition of treatment plan genetic make-up [4]. Technology application in virtual patient environments increases patients' involvement and attunement, agency in decision-making. Automated intelligent technology empowers real-time evaluation of treatment approaches without compromising patient's benefits and virtual trial makes treatment customization possible. These experiences may be defined as branches of knowledge that give unlimited access to learners and a chance in metaverse applications enabling ongoing education and professional growth in the field of medical education. In addressing concern and getting to solutions, everyone involved in patient care and administration must work together to set the boundaries of safety in the experimentation of new techniques. In conclusion, the importance of the metaverse can be harnessed for explicit benefits improving clinical outcomes to further the progress of medicine.

8 Case Studies and Use Cases in Healthcare Metaverse Integration

Study and also usage situations in healthcare metaverse combination display the varied applications as well as transformative capacity of online atmospheres in healthcare shipment illness administration as well as preventative healthcare campaigns. This area discovers real-world instances plus circumstances where the metaverse is incorporated right into health care setups to boost individual results plus boost public wellness treatments [23]. Digital health centers as well as centers take advantage of immersive online settings to supply health care solutions from another location, removing geographical obstacles along with boosting accessibility to look after people. These digital centers use a variety of clinical solutions consisting of telemedicine examinations digital examinations, remote tracking plus digital recovery programs. By incorporating digital medical facilities along with centers right into health care systems, service providers can expand their reach, maximize source application, as well as supply top quality like people in underserved or remote

locations. Digital atmospheres are used for illness security plus break out monitoring, making it possible for medical care companies coupled with hygienics authorities to keep an eye on along with track transmittable conditions in real-time [7].

Online monitoring systems accumulation as well as assess information from different resources, consisting of digital wellness documents, social networks and also wearable gadgets to recognize condition fads, hotspots as well as arising break outs. Lack of complete patient information ultimately helps the clinicians to find an ideal treatment plan based on the rendition of treatment plan genetic make-up [4]. Digital settings are utilized for wellness along with preventative health care efforts encouraging people to take aggressive actions to keep their wellness coupled with well-being. Online health systems use tailored wellness analyses, physical fitness programs dietary advice along with psychological health and wellness assistance solutions, customized to people's one-of-a-kind demands as well as choices. By involving customers in immersive plus interactive experiences, digital health campaigns advertise wellness education and learning, actions modification coupled with self-management techniques encouraging people to lead much healthier way of lives plus stop persistent illness [23].

As shown in Table 6, virtual hospital is a concept that entails the use of online platforms to deliver healthcare to patients since distances are no longer a barrier that prevents one from accessing a doctor [21]. Disease Surveillance means the process of collecting and monitoring data for diseases to locate bad affected areas, diseases epidemics and increasing prevalence of diseases in real time to allow for early and appropriate responses and interventions. It promotes and provides programs in health and preventative care initiatives and services such as health-authorized health assessment, fitness, and mental health support for one to be empowered to live a healthy lifestyle.

Table 6 Case studies: innovations in healthcare delivery and disease management

Case study	Description
Virtual hospitals	Leverage immersive online environments to provide remote healthcare services, enhancing accessibility and overcoming geographical barriers
Disease surveillance	Gather and analyze data from various sources to identify disease trends, hotspots, and outbreaks in real-time, enabling timely interventions and resource allocation
Health and preventative care initiatives	Offer personalized health assessments, fitness programs, nutritional guidance, and mental health support services to empower individuals in leading healthier lifestyles and preventing chronic diseases

9 Conclusion

The integration of metaverse technologies into healthcare offers transformative possibilities for enhancing patient care, improving health outcomes, and driving innovation across the healthcare landscape. Through immersive virtual environments, advanced data analytics, and artificial intelligence, the metaverse enables personalized medicine, remote patient monitoring, and virtual healthcare delivery, revolutionizing healthcare practice, research, and policy. The metaverse combines digital innovation with medical practice, providing immersive virtual environments where stakeholders redefine healthcare delivery. Virtual reality, augmented reality, and artificial intelligence drive the convergence of the metaverse and healthcare intelligence, enabling personalized medicine and remote patient monitoring. Metaverse-driven healthcare intelligence spans healthcare delivery, research, education, and preventive healthcare, offering avenues for improving patient outcomes and advancing population health.

In healthcare practice, virtual environments and advanced technologies enhance patient care and clinical decision-making. Virtual hospitals, telemedicine, and remote monitoring transform the healthcare experience. Virtual laboratories and collaborative platforms accelerate drug discovery and medical innovation, addressing complex healthcare challenges. From a policy perspective, clear guidelines and regulatory frameworks are necessary to ensure ethical and responsible use of virtual healthcare technologies, safeguarding patient rights and promoting trust. Looking ahead, the future of healthcare lies in the convergence of metaverse technologies and intelligence-driven systems. Patients will access personalized healthcare services through virtual environments, while healthcare professionals leverage virtual reality and AI to enhance clinical workflows. Preventive healthcare initiatives will promote healthy behaviors through virtual wellness centers, while disease surveillance will leverage predictive analytics in real-time. This future represents a democratized approach to healthcare, breaking down barriers and empowering individuals to take control of their health. By embracing metaverse-driven healthcare intelligence, stakeholders can collaborate to create a future where everyone has access to equitable, effective healthcare services, leading to healthier, and happier communities worldwide.

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The Notion of Privacy Rights in the Metaverse: Examining Legal Hemispheres in India's Digital Era

Poonam Gulati and Kusum Pal

Abstract The evolution of the metaverse heralds a transformative era in the digital sphere, offering both unprecedented prospects and complexities, notably in the domain of privacy rights. This paper undertakes a comprehensive exploration of the intricate interplay between privacy rights, intellectual property (IP), and information technology (IT) within the context of India's burgeoning digital era. Centered on the metaverse as a pivotal shift in virtual interaction paradigms, the study scrutinizes the legal frameworks governing privacy rights, intellectual property, and information technology in India. The right to privacy has metamorphosed into a foundational entitlement in India, imbued with significance across diverse domains. While privacy conventionally connotes "freedom from interference," its purview encompasses communicational privacy, information privacy, intellectual privacy, and beyond. This research delineates the evolution of the right to privacy in India and its resonance across the metaverse and disparate legal hemispheres. The trajectory of defining privacy rights in independent India spans from 1954 to 2017, notably culminating in the recognition of privacy rights as fundamental under Article 21 of the Indian Constitution. This constitutional acknowledgment has catalyzed discourse on privacy jurisprudence, particularly vis-à-vis digital terrains and the confluence of IT and IP laws. The escalating usage of the internet has impacted the expanding use of the metaverse amplifying their combined impact across various legal strata. Moreover, the proliferation of AI and advanced data processing techniques portends a blurring of boundaries between physical and virtual realms, thereby posing novel challenges to user privacy. The confluence of IT and IP protection underscores the imperative for comprehensive privacy regulations, particularly in the realm of data privacy. Employing a synthesis of legal scholarship and contemporary case analyses, the research dissects the multifaceted dimensions of privacy rights in the metaverse, discerning the ramifications of emergent technologies like virtual reality, augmented reality, and artificial intelligence. Furthermore, it delves into the confluence of privacy rights with intellectual property laws, meticulously examining issues pertaining to digital content ownership, copyright infringement, and trademark protection within

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virtual environments. Methodologically, this study employs critical analysis and scrutiny of legal precedents, case law, and legislative frameworks germane to privacy rights, IT laws, and IP rights. The investigation has yielded several salient findings: foremost among them being the constitutional recognition of privacy as a fundamental right, the exploration of the nexus between IT laws and IP rights concerning data privacy, and the imperative for robust privacy regulations. Against the backdrop of rapid technological advancements and regulatory reforms, this research elucidates the evolving legal hemispheres of intellectual property and information technology in India. It undertakes a critical evaluation of extant legal frameworks, assessing their efficacy in safeguarding privacy rights in the metaverse, while identifying lacunae and proposing avenues for regulatory enhancement. By illuminating the intricate nexus between privacy, intellectual property, and technology, this paper contributes to a nuanced comprehension of the legal challenges and opportunities engendered by the metaverse in India's digital epoch. Keywords: Privacy rights, AI, metaverse, digital era, right to privacy, data privacy, information technology laws, intellectual property rights, Digital Personal Data Protection Act 2023, India.

1 Introduction

The evolution of the metaverse heralds a transformative era in the digital sphere, offering both unprecedented prospects and complexities, notably in the domain of privacy rights. The concept 'Metaverse' is the newbie of the twenty-first century, which started with the birth of the internet/web. This advanced level of internet experience also known as Web 3.0 is an enhanced version of internet applications promising to deliver a spatial experience to the users. In fact, now it is smearing the margins existing in between the factual world and digital world [1]. It is believed that the advancement of Metaverse will significantly enhance new opportunities, working environment, and digital economies. However, the picture cannot be taken as green on all the fronts. This amalgamation of the virtual-real world relies extensively on sharing data, which is of grave concern. The concern is directly related to the question of data privacy rights, the subject which has lately become a global concern. The interrelation between the Metaverse and data is that to provide a superior experience to the users through extended reality,[1] the devices used in Metaverse extracts huge information of its users in the form of data which also includes biometrical statistics [2]. Among the data collected in the process, even the sensitive information of the users becomes vulnerable. Thus, the subject of data privacy has become pivotal [3].

Indeed, data drives economies [4], and with the expansion of digital technology usage in field of healthcare, tourism, education, entertainment, etc., information is quickly digitized and circulated, and abundant devices collect and generate data [4]. The proliferation of data is astounding, with the prediction that the global volume of data will grow to 175 zettabytes by 2025 [5]. A data asset is the lifeline of all

[1] Like XR gears (e.g., head-mounted displays or HMDs).

businesses and needs to be secured for the fulfilment of appropriate and intelligent decision-making in all spheres of expansion. All kinds of data, whether personal or non-personal, sensitive [6], or non-sensitive are priceless and not easy to keep away from exploitation. Without a doubt data is a commodity that can be bought, sold, or misused in a potentially devastating manner hence, there is a need to protect and preserve it.

The erosion of privacy is becoming an imminent concern. While delivering a keynote in 2018, in Brussels, Tim Cook, CEO of APPLE, referred to the statement, "*Gossip is no longer the resource of the idle and the vicious, but has become a trade.*"

A data breach is a highly aversive incident that is rife with uncertainty about how the compromised data will be used by unauthorized third parties [3]. Issues related to privacy have to walk out of academic discussions and conferences and be visible in the circle that gives it recognition and protection. After years of deliberations and consultations, and multiple attempts at legislation, India has enacted a data protection law [7]. These laws attempt to govern data privacy issues and the coming decade shall have a strong regime through the length and breadth of the privacy landscape vis a vis growth of Metaverse in our country.

2 Understanding the Concept of Metaverse

Every passing day we are observing how strongly digital technology is getting integrated with our real life. This conversion of the real world into a virtual world experience is what in simple terms can be stated as Metaverse. Since Metaverse is still in its budding stage, thus it becomes difficult to enclose this word in a proper definition. Nevertheless, the characteristics of Metaverse can be grouped under four major heads i.e. Socialisation, Immersive interaction, Real world building, and Expandability [8]. Socialisation is the characteristic that enables internet users to interact with others through internet platforms.[2] Immersive interaction assists the users to have enhanced human–machine interactions,[3] without depending upon the final interpretation through the conventional methods of sentences, videos, and images. Real world-building is like designing an imaginary world that provides users with virtual spaces to carry out various real-life activities like shopping, playing, and meeting. The last characteristic embodied in Metaverse is Expandability since it encompasses all the possibilities to extend more, than the real world, giving enhanced power to its users in fantasy and science fiction [8].

However, now with time, Metaverse is breaking all the barriers and in addition to the above-mentioned characteristics, it is also proving an opportunity for its users to enjoy their own created cyber life along with their real-life where they have the

[2] Like Facebook, Snapchat, Instagram etc.

[3] The examples of immersive interactions are like interactive scrollytelling stories, data storytelling, Hubspot's website grader etc. It majorly relies upon eXtended Reality (XR) and brain-computer interface.

power to create their friends, business and such activities carried out in non-virtual life pattern.

3 Technologies Behind Metaverse

The discussion upon understanding the Metaverse will be futile if one is ignorant about the technologies that back up the Metaverse. Technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and 3D Modelling provide the fundamental design of Metaverse.

AI is the theoretical development of a computer system that performs the conventional tasks requiring human intelligence like making decisions, or to say recognising speech, or even absorbing various patterns of human beings. Metaverse is an umbrella term covering various technologies like deep learning, human learning, or even natural language processing.

IoT is a physical device capable of transferring data without any human intervention to others. It includes a sensor assigned to a unique identifier with the primary objective of creating self-reporting devices. Smart Home Devices, Smart Watches, and Self-Driving Cars are a few of the best examples of IoT.

Representing any object or surface in three-dimensional form with the help of computer graphics is said to be 3D Modelling. This 3D Modelling assists the users to enjoy the immersive experience in the best form on the Metaverse platform.

In addition to it, Metaverse also delves into Spatial and Edge Computing. Spatial computing encompasses concepts like augmented reality (AR),[4] virtual reality (VR),[5] Mixed reality (MR), and Extended reality (XR).

4 Privacy Threats Through Metaverse

It cannot be ignored that Metaverse functions highly upon the data of the users since the four characteristics highly depend upon the user's choice and revelation of personal data by the users. Severe threats like private information outflow, unauthorised access, data injection, and phishing, keep looming upon the users. There remains a persistent threat that this personal information can be mishandled by unauthorised persons for their personal gains, like to state, hacking of humans' physical traits by hackers with the assistance of technology connected to Metaverse used for their wrongful gains.

[4] Augmented Reality is an amalgamation of digital information with the users' real time environment.

[5] VR is a complete immersive visual environment blocking the real environment view and replacing the same with the virtual world.

Indeed, it would be appropriate to state that the advent of emerging technologies such as artificial intelligence (AI), machine learning, and huge data analytics presents both opportunities and challenges for data privacy regulation. While these technologies offer transformative capabilities in various sectors, including healthcare, finance, and marketing, they also raise concerns regarding the collection, processing, and utilization of vast amounts of personal data. For instance, AI-powered algorithms can analyse individuals' online behavior, preferences, and sentiments to deliver personalized recommendations and targeted advertisements. However, the indiscriminate collection and utilization of personal data without adequate consent and transparency may infringe upon individuals' privacy rights and autonomy. Furthermore, the proliferation of Internet of Things (IoT) devices, ranging from smart home appliances to wearable gadgets, amplifies the volume and diversity of data generated and transmitted across networks. This poses serious challenges for data protection and security, leading to unauthorized access and misuse of sensitive information.

5 The Global Aspect of the Concept of Data Privacy

Looking back towards the evolution of the right, in 1948, the first statutory recognition was given to the Right To Privacy by Article 12[6] of the Universal Declaration of Human Rights (UDHR) [9], and in due compliance, the provision of privacy was induced by countries by way of ratification.

It has been explicitly stated through the OECD that to ensure the safety, dignity, and freedom of thought and expression, it is essential to safeguard and protect people's privacy. Wherein the enhancement in digital technology brings easy access to our lives, nevertheless, it also imposes a grave concern to privacy issues. Such an issue cannot be resolved unless there is transnational cooperation between all the nations.

Post-1980, globalization introduced a transborder flow of data along with economic, political, and cultural exchanges all over the world. The Organisation for Economic Cooperation and Development (OECD) in September 1980, set out eight principles of OECD Privacy Guidelines that act as minimum guiding principles for member states that safeguard personal data. The said guidelines[7] govern the protection of privacy and transborder flows of personal data whereby the basic principles recognizing privacy were born.

Various international treaties and agreements have played a significant role in shaping the landscape of global data privacy regulations. For instance, the Council of Europe's Convention for the Protection of Individuals concerning Automatic Processing of Personal Data, also known as Convention 108 [10], serves as the

[6] No one shall be subjected to arbitrary interference with his privacy, family, home, or correspondence, nor attacks upon his honor and reputation. Everyone has the right to the protection of the law against such interference or attacks.

[7] The OCED guidelines, 'Part Two. Basic Principles Of National Application' 14. A data controller should be accountable for complying with measures which give effect to the principles stated above.

first legally binding international instrument for data protection. Adopted in 1981 and revised in 2018, Convention 108 [11] establishes principles for the security of personal data and promotes cross-border data flows while ensuring individuals' privacy rights. Moreover, the Budapest Convention [12] on Cybercrime, developed by the Council of Europe in 2001, addresses various forms of cybercrime, including unauthorized access to computer systems and data, computer-related fraud, and violations of intellectual property rights. Ratified by numerous countries, including India, the Budapest Convention facilitates international cooperation in combating cyber threats and harmonizing legal frameworks for cybercrime prosecution.

In Europe, the General Data Protection Regulation (GDPR) [13], enforced in 2018, is one of the most comprehensive and stringent data protection laws globally. The GDPR not only imposes strict requirements on how personal data should be processed and protected but also extraterritorially affects businesses operating within the EU or handling the data of EU residents. Its data minimisation, purpose limitation, and accountability principles have set a benchmark for data protection standards worldwide [14].

Similarly, countries in other regions have been revising their data protection frameworks to align with evolving technological landscapes and global best practices. For instance, Brazil's General Data Protection Law (LGPD) [15], enacted in 2018 and fully enforced in 2020, mirrors many aspects of the GDPR and aims to enhance privacy rights and data sovereignty for Brazilian citizens. In the Asia–Pacific region, countries like Japan, South Korea, and Singapore have implemented or are in the process of formulating robust data protection regulations. Japan's Act on the Protection of Personal Information (APPI) [16] and South Korea's Personal Information Protection Act (PIPA) [17] are noteworthy examples of legislative efforts aimed at safeguarding individuals' privacy rights in digital environments.

Moreover, international collaborations and initiatives play a crucial role in harmonizing data protection standards and fostering cross-border cooperation in combating global data privacy challenges. For instance, the Asia–Pacific Economic Cooperation (APEC) [18] has developed the Cross-Border Privacy Rules (CBPR) system to facilitate safe data flow among member economies while ensuring consistent data protection standards.

6 Intellectual Property Challenges Related to Data Protection in the Metaverse

The metaverse is a digital realm where individuals and businesses interact in a virtual three-dimensional space. As more people enter this space, the question of who owns intellectual property (IP) rights to virtual assets and creations becomes increasingly complex. It is pertinent to explore the challenges and opportunities that IP presents in the metaverse, focusing on digital content ownership, copyright infringement,[8] and

[8] Indian Copyright Act, 1957: Provides detailed guidelines on copyright protection in India.

trademark protection.[9] The emergence of the metaverse has flickered discussions about the need for new regulations to govern these digital phenomena.

6.1 Digital Content Ownership

The Metaverse, an interconnected virtual environment, presents significant challenges and opportunities for digital content ownership. Users can create and interact with virtual representations of real-world objects, necessitating respect for intellectual property (IP) rights. IP laws protect the intangible elements of both physical and virtual objects and ensure that creators and rights holder can control their works within the Metaverse. Most importantly, (i) Copyright Law protects virtual creations like avatars, buildings, and landscapes. (ii) Trademark Law safeguards logos and branding materials used in virtual worlds. (iii) Patent Law applies to technological advancements, though determining infringement can be complex.

Furthermore, Non-fungible tokens (NFTs), based on blockchain technology, provide clear digital ownership. NFTs are unique, allowing them to be sold or traded with a digital ledger recording transactions. They can embed various content types, creating valuable digital files. Data exploitation in the future bring forth virtual platforms like Second Life, Fortnite, and Roblox offering extensive data exploitation opportunities. However, the full realisation of the Metaverse requires significant computing power and standardized protocols.

6.2 Copyright Infringement

Copyright laws grant exclusive rights to authors over their original works, covering various forms of expression. This protection extends to digital environments, including the Metaverse and NFTs. International Agreements and Adaptations such as the (i) Berne Convention establishes minimum standards for copyright protection globally, ratified by 181 countries. It mandates the protection of authors' rights regardless of the form of expression. (ii) WIPO Copyright Treaty adapts the Berne Convention to digital environments, clarifying that storing a protected work in digital forms, such as an NFT or a file displayed in the Metaverse, constitutes reproduction requiring the copyright holder's prior approval.

In the metaverse, any use of copyrighted content requires authorization from the copyright holder. The precedents observed include (i) MDY Industries, LLC v. Blizzard Entertainment, Inc.[10] wherein the US District Court for the District of Arizona ruled that a software program allowing users to automatically play World of Warcraft infringed on Blizzard's copyright. (ii) In NODWIN Gaming Case the

[9] Trade Marks Act, 1999: Governs trademark registration and protection in India.

[10] 629 F.3d 928.

Delhi High Court granted a permanent injunction against entities using NODWIN Gaming's logo and branding in a mobile game without permission, emphasizing the importance of respecting copyright in virtual spaces. (iii) Solid Oak Sketches v. NBA 2 K[11] the court ruled in favor of the game publisher, citing defenses like de minimis use, implied license, and fair use, based on the artistic nature of the video game. Hence to protect the Copyright in the Metaverse, the copyright owner needs to (i) Registration of works with relevant authorities to strengthen your legal position. (ii) Monitoring for instances of infringement. (iii) Take legal action against infringers to enforce your rights. (iv) License the IP to others to control its use. (v) Create terms of service agreements to manage how your IP is used in the Metaverse. Thus, copyright laws ensure that authors maintain control over their works in both physical and digital environments. By understanding international agreements, legal precedents, and protective measures, creators can effectively safeguard their IP in the Metaverse.

6.3 Trademark Protection

Trademark protection in the Metaverse adheres to established legal principles, safeguarding trademarks regardless of their use in physical or digital contexts. The primary challenge lies in defining the boundaries of trademark use in virtual environments. The precedents observed include (i) AM General LLC v. Activision Blizzard[12] in this case, the court applied the Rogers test to determine if the use of the Humvee trademark in the Call of Duty video game required prior authorization. The court concluded that the use had artistic relevance and was not explicitly misleading, thus not requiring prior authorisation. (ii) Exphar SA v. Eupharma Laboratories Ltd.[13] wherein the Delhi High Court held that using a trademark similar to the plaintiff's trademark in a virtual world constituted trademark infringement due to potential consumer confusion. These cases highlight the necessity for careful consideration of trademark use in digital spaces to avoid infringement.

To protect your trademarks in the metaverse it is essential to register your marks with the appropriate authorities, monitor for unauthorized use, and enforce your rights through legal action if necessary. Licensing agreements and terms of service can also help manage the use of your trademarks in virtual environments. Trademark protection in the Metaverse requires adherence to established legal principles while navigating the unique challenges of digital environments. By registering trademarks, monitoring for unauthorized use, and enforcing rights through legal action, trademark owners can safeguard their brands in virtual spaces. Licensing agreements and terms of service further help manage trademark use, ensuring protection across both physical and digital realms.

[11] No. 16-CV-724-LTS-SDA.

[12] 17 Civ. 8644 (GBD).

[13] AIR 2004, Supreme Court, 1682.

7 Legal Frameworks Governing Data Privacy in India

The journey of defining the right to privacy in independent India spans between 1954 and 2017. The interpretation of Article 21 has given a multi-dimensional expansion to the right to privacy due to judicial interventions, its journey from MP Sharma v. Satish Chandra[14] in 1954 to Justice K. S. Puttaswamy v. Union of India[15] in 2017, has climbed many ladders, wherein the landmark rulings of case laws namely M. P. Sharma and Kharak Singh[16] were reversed [19] and the judges unanimously ruled in favour of the right to privacy as fundamental under Article 21 of the Constitution of India. The consequences of this verdict are not limited to the Aadhar Identification Scheme Case in which it was pronounced. This judgment highlighted the need for a data protection regime in India, impacted on data privacy and their protection-related issues wherein the role of governmental control over personal and big data became questionable, and its impact on the non-governmental sector i.e., the private sector, the sphere of online information privacy could not be overlooked. Hence debates and deliberations affected the enactment of the Digital Personal Data Protection Act 2023 (DPDP Act) which became the first privacy regime in India, making data privacy much more than just a consumer right, in addition to the rights conferred under Information Technology Act 2000 and IP Laws.

7.1 Information Technology Act, 2000

The concept of privacy laws in India has been witnessed by data privacy brought about by the Information Technology (IT) Act. In 2000, the Information Technology Act was legislated to address the long-pending issue of data protection. The focus was to take care of two basic concerns, firstly dealing with compromises related to SPDI i.e., Sensitive personal data or information,[17] wherein wrongful loss(s) or wrongful gain(s) occurring due to negligence are addressed. Secondly, the act purports to deal with the intentional disclosure of SPDI that was revealed under contractual relationships. The amendment of 2008 in the Act, introduced Section 43A imposing an obligation to protect all sensitive personal data, and followed by rules in 2011, the government of India introduced Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules 2011 also known as 'Indian Data Protection Rules' under the Act to be read with Section 43A.

[14] AIR 1954 SCR 1077.

[15] (2017) 10 SCC 1.

[16] (1963) AIR 1295.

[17] SPDI is defined as sensitive personal data or information that can identify a natural person consisting of (i) passwords, (ii) financial information such as Bank Account or credit card or debit card or other payment instrument details, (iii) physical, physiological and mental health conditions, (iv) sexual orientation, (v) medical records and history, (vi) biometric information.

7.2 Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011

Information Technology Act, 2000, is further supplemented with Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011 [20] ("Data Protection Rules"). These rules specifically regulate the following (i) Personal Information (PI) The Data Protection Rules define 'personal information' as "any information that relates to a natural person, which, either directly or indirectly, in combination with other information available or likely to be available with a body corporate, is capable of identifying such person." While the IT Act and the Data Protection Rules do not impose specific compliance requirements for entities handling personal information, penal provisions apply to offenders who unlawfully disclose personal information obtained during service provision under a lawful contract, intending to cause or knowing that such disclosure is likely to cause wrongful loss or gain. (ii) Sensitive Personal Data or Information (SPDI) is defined under the Data Protection Rules to include: "password; financial information such as bank account or credit card or debit card or other payment instrument details; physical, physiological, and mental health conditions; sexual orientation; medical records and history; and biometric information." Entities in India that collect, store, process, disclose, or transfer SPDI must comply with several requirements, such as obtaining user consent, notifying users of SPDI collection, publishing a privacy policy, appointing a grievance officer, and adopting reasonable security practices. These compliance requirements currently apply only to Indian entities. However, the IT Act can have extraterritorial jurisdiction if there is a sufficient nexus to India, meaning non-Indian entities could also be subject to penalties for non-compliance.

7.3 Intellectual Property Laws in India

Indian Patent Act,1970, confers the patent holder the right to approach the court under the suit of Infringement against the exclusive ownership rights he obtains upon the property through the provisions of the said Act.[18] In such cases, the burden of proof related to infringement lies upon the person who claims the patent right upon such object (who is called the patentee). However, Section 104A, which was inserted under the regulations of the TRIPS agreement, provides an exception to the same and states that in case the patented subject matter is a new product, as well as the patentee claiming his right, failed even after his reasonable effort to identify that the identical product is made out of the same process, the burden of proving the same will fall upon the other party.

[18] Chapter III of Indian Patent Act, 1970.

The Indian Copyright Act, 1957, protects the owner's right from infringement through Section 63B of the Act and states that any person infringing the copy of a computer program shall be imprisoned for a minimum duration of six months extending up to three years. Copyright upon the data is thus completely recognised by our Indian judiciary.

Similar provisions are also witnessed under the Indian Trademark Act, 1999, wherein the author of the Trademark[19] is empowered to file a suit of infringement.[20]

7.4 Digital Personal Data Protection Act 2023

The Central Government of India has issued standards to control data collected by the community from users, such as the Digital Personal Data Protection (DPDP) Act, 2023 which is yet to be implemented.[21] The **Digital Personal Data Protection Act, of 2023** has been a significant milestone in India's digital rights landscape and was notified on August 11, 2023 [21]. The key highlights of the DPDP Act include (i) the lawful basis of processing is consolidated by this Act to consent and certain legitimate uses. (ii) Data localisation rules are relaxed allowing data transfers across jurisdictions unless specifically notified. (iii) Data processing agreements must be formulated between organisations and third parties before outsourcing activities (iv) Non-compliance with the law can result in financial penalties of up to INR 250 crore per instance. (v) Significant data fiduciaries must conduct periodic Data Protection Impact Assessments. (vi) Personal data already in the public domain is excluded from the Act's scope.

Furthermore, the Act aims to empower individuals, redefine business practices, and usher in a new era of responsible data handling. It emphasizes privacy and provides individuals with data processing rights. The keenly awaited piece of legislation has huge ramifications for technology and other important sectors of the economy since it prescribes several provisions regarding the collection, processing, and storage of data of Indians. (Economic Times, 2024) [22] However, The Act is expected to come into force in July 2024 through a government notification (Archana Rao, 2024) [23]

In line with this, the Bureau of Indian Standards (BIS) issued IS 17428, mandating organizations to follow proper privacy practices when collecting data. The standard requires periodic audits and necessitates that organizations establish, document, and maintain mechanisms to reduce the risk of data breaches and protect data privacy.

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[19] Chapter II, Trademark Act, 1999.

[20] Section 29, Trademark Act 1999.

[21] Currently, data protection is governed by the Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011, notified under the Information Technology Act, 2000. These Rules require organizations to demonstrate compliance by maintaining documented security programs and security policies that include technical, security, and physical measures.

This regulatory framework aims to create a safe environment for data regulation within the metaverse in India.

However, the metaverse is a global digital realm where users can interact from any part of the world, posing challenges to the applicability and effectiveness of these standards. The BIS standards, for instance, do not apply to foreign organizations operating in India or Indian organizations operating abroad, limiting their efficacy in the context of the metaverse. Additionally, overarching regulation of the metaverse is often critiqued for potentially infringing on the right to freedom of speech and expression. For example, Section 69 of the Information Technology Act, 2000, empowers the Government to intercept or remove information in the interest of state security and integrity, raising concerns about government surveillance and censorship within the metaverse. The extent to which the metaverse can be regulated under the IT Act remains uncertain. To further address these challenges, India has proposed the Digital India Act and the DPDP Act, 2023, which are yet to be passed and implemented. The Telecom Regulatory Authority of India (TRAI) is currently seeking comments on its consultation paper, which will lead to the finalization of standards applicable to the metaverse. This ongoing regulatory development highlights India's efforts to balance innovation and user protection in the evolving digital landscape [24].

8 Challenges in Safeguarding Privacy in Emerging Technologies

The metaverse, enabled by technologies such as augmented reality (AR), virtual reality (VR), and blockchain, offers immersive experiences where users adopt digital avatars. However, this digital realm raises significant data privacy issues, particularly as AR/VR technologies capture users' biometric data and facial gestures. Effective privacy protection is paramount, requiring practices like data transparency, improved regulations, better controls, and technical design enhancements.

Web 3.0 and Privacy Challenges: Web 3.0 has introduced innovations, with the metaverse being a notable advancement. Despite its potential, the metaverse poses significant privacy risks for stakeholders, including developers, service providers, regulatory bodies, and users. Managing privacy from the outset is crucial, necessitating robust legal and technical measures to protect user data and ensure transparency.

Personal Data and Biometric Privacy: The metaverse's capability to track real-time physiological responses and collect sensitive biometric data necessitates strict controls to prevent misuse. The data collected can fall under 'sensitive' categories and, if unprotected, may lead to privacy violations through social engineering or cyber-attacks. Effective privacy protection requires consent, careful data collection, and transfer regulations to prevent misuse by unregulated entities.

9 Identifying Legal Lacunae

The General Data Protection Regulation (GDPR) and other existing privacy laws provide a foundation for data protection. However, they require amendments to address the unique challenges posed by the metaverse. For instance, the GDPR's provisions on data collection, processing, and transfer need to be adapted to cover the extensive data generated in the metaverse.

Cross-Border Data Issues: Data transfer across borders in the metaverse raises additional concerns. For example, data about a user's interaction with a virtual brand may be transferred internationally, necessitating compliance with varying regional data protection laws. Regulations must ensure that sensitive data, especially from vulnerable groups like children or patients, is adequately protected during cross-border transfers.

Decentralization and Blockchain Risks: Blockchain and cryptocurrency introduce further complexities. While these technologies offer secure and pseudonymous transactions, issues such as verifying user identities and preventing fake domain names or smart contracts require regulatory attention. Additionally, the immutable nature of blockchain poses challenges for data deletion and the 'right to be forgotten'.

10 Proposing Avenues for Regulatory Enhancement

New Regulations and Amendments: -Governments must update existing legislation or enact new laws tailored to the metaverse. The EU's Digital Services Act and Digital Markets Act are steps in this direction, proposing strict regulations on data usage and core platform services. The proposed EU AI Act could play a crucial role in regulating avatars' identities and related content.

Privacy-by-Design and Architectural Security:—Incorporating privacy-by-design principles and architectural security from the development stages of metaverse platforms is essential. This includes implementing technical solutions like anonymization, pseudonymization, and secure data transfer protocols, alongside legal measures to ensure compliance with privacy standards.

Cross-Border Agreements and Compliance:—To address cross-border data security, technologies such as confidential computing can protect data in transit. Privacy experts should ensure compliance with existing regulations and agreements like the GDPR Standard Contractual Clauses. Transfer risk assessments and data privacy impact assessments are vital for mitigating privacy risks in international contexts.

Industry-Specific Regulations:—Specific industries exploring the metaverse, such as healthcare, require stringent data protection measures. Legislation like the Health Insurance Portability and Accountability Act (HIPAA) [25] in the US and GDPR in

Europe provide frameworks for protecting sensitive health data. These regulations need to be adapted to ensure comprehensive protection in virtual environments.

Enhanced Regulatory Cooperation:—Metaverse developers must collaborate with governments and international bodies to create universally recognized protocols and legally binding regulations. This cooperation is crucial for addressing the complex legal and privacy challenges in the metaverse.

Proactive Privacy Measures:—Adopting proactive privacy measures, such as setting clear privacy standards and engaging in early design considerations, can help mitigate risks. Transparency, compliance with legislation, and stakeholder responsiveness are key benefits of proactive privacy governance.

Treatment of Digital Avatars under the Law:—In the Metaverse, a user's digital avatar represents their character. These avatars, which can indirectly identify the user, might be considered an extension of the user's personality and, consequently, their personal data. Digital avatars that incorporate biometric data, such as digital fingerprints or facial expressions linked to real-world biometric authentication (e.g., eye-tracking or pupil dilation), may be classified as Sensitive Personal Data (SPD) under Indian law. The DPDP Act empowers the Indian government to prohibit the processing of certain biometric data categories. Therefore, companies operating in the Metaverse must navigate regulatory uncertainties regarding their Indian operations.

Data Portability:—If digital avatars and unique digital assets are deemed personal data or SPD, the rights of data principals related to such data will extend to these avatars and assets. Porting digital avatars and assets across different Metaverse platforms presents technical and legal challenges, including maintaining seamless, accurate, and high-fidelity data transfer. Additionally, when digital assets are co-created by multiple users, data portability becomes complex due to the need for conflicting permissions from multiple rights holders. This raises significant issues in ensuring consistent user experiences and legal compliance across platforms.

Anonymity and Harms:—The anonymity afforded by online communications and interactions has been both a boon and a bane. While it promotes free expression, it also facilitates harmful behaviors like fake news dissemination, hate speech, and trolling. Governments worldwide, including India's, are reevaluating the necessity of absolute anonymity online. In October 2020, the Five Eyes intelligence alliance, along with Japan and India, issued a joint statement emphasizing the balance between "End-To-End Encryption and Public Safety." [26] Following this, India's Information Technology (Intermediaries Guidelines and Digital Media Ethics Code) Rules, 2021[22] (IT Rules) [27] require significant social media intermediaries to enable the tracing of message originators.[23] Given these developments, the Metaverse cannot rely on default anonymity. Instead, the focus should be on preventing privacy harms

[22] Under the IT Rules a 'significant social media intermediary' means a "social media intermediary having number of registered users in India above such threshold as notified by the Central Government".

[23] Rule 4(2) of IT Rules.

through robust security measures for identity data and digital avatars, addressing issues like identity theft and phishing attacks.

Balkanization of the Internet and Impact on the Metaverse:—The DPDP ACT proposes data residency requirements for certain data categories, such as SPD and CPD. This mandates Metaverse operators to store some data on physical servers within India. Given the global nature of Metaverse platforms, such jurisdiction-specific requirements could fragment user experiences across different regions, complicating seamless interaction within the Metaverse.

Innovations in Privacy for the Metaverse:—Modern privacy regimes often rely on user consent for data processing. However, users may not fully understand the implications of data processing activities within the Metaverse, leading to consent fatigue. Therefore, a transition to a "privacy by design" approach is recommended. This approach integrates privacy-enhancing features into the Metaverse architecture, mitigating privacy harms. Innovations such as blockchain-based zero-knowledge proofs and tokenized data storage on secure edge devices (like AR/VR headsets) could safeguard privacy [28]. Decentralized Autonomous Organizations (DAOs) offer another approach, enabling users to participate in shaping privacy policies through governance tokens, fostering user-centric privacy governance [29].

Metaverse and Larger Open Data Policies:—The Metaverse will collect and process large amounts of personal data and non-personal data (NPD). With the government proposing mandatory NPD sharing for better service distribution and policymaking, evaluating if Metaverse-related data should be shared is crucial. For centralized Metaverse models, NPD may be a competitive differentiator. Therefore, voluntary data sharing should be encouraged to promote interoperable Metaverse experiences. Entities should control which data sets enable interconnected and seamless Metaverse interactions.

11 Key Findings and Suggestions

The Metaverse mirrors the internet's development, necessitating robust legal frameworks to manage new technological advancements and associated legal issues.

The Metaverse will require strong cybersecurity measures to protect user data and virtual properties, especially with the advent of quantum computing.

The overlap between IT and IP laws necessitates comprehensive privacy regulations to protect data in the evolving digital landscape.

The DPDP Act establishes a fiduciary relationship between data principals and fiduciaries, with extraterritorial applicability.

Indian Organizations must adapt to the DPDP Act by appointing Data Protection Officers, conducting privacy impact assessments, and ensuring consent management.

12 Conclusion

As India transitions into a digital era, the protection of privacy rights becomes paramount. The DPDP Act 2023 represents a significant step towards robust data privacy and protection, drawing on global best practices like the EU-GDPR. The DPDP Act 2023 marks a significant step towards safeguarding individuals' data rights, aligning with global data protection standards. However, the rapid evolution of technology and the expanding digital landscape, particularly with the rise of the Metaverse, present ongoing challenges.

Effective implementation and enforcement of data protection laws, coupled with robust cybersecurity measures, will be crucial. Businesses must adapt to new regulatory requirements and invest in securing personal data. User awareness and empowerment will play a vital role in protecting privacy rights. As the Metaverse and other emerging technologies reshape our interactions with the digital world, robust legal frameworks and proactive measures will be essential to ensure that privacy rights remain a fundamental aspect of India's digital era.

Balancing innovation by securing IP rights in the Metaverse is an extra leap with privacy protection requiring a collaborative approach involving regulators, businesses, and users. As India continues to refine its data privacy landscape, fostering public–private partnerships and engaging in international discussions will be essential to create a secure and resilient digital future.

In conclusion, the recognition of privacy rights as a fundamental right under Article 21 of the Indian Constitution underscores the importance of comprehensive privacy regulations. As the Metaverse and other emerging technologies reshape our digital and physical landscapes, a proactive and adaptive approach to data protection will ensure that privacy rights are upheld in India's evolving digital era.

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Metaverse in Healthcare Integrated with Explainable AI and Blockchain: Enabling Immersiveness, Ensuring Trust, and Providing Patient Data Security

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Abstract Healthcare has always benefited greatly from automation and digitization. It accepts all cutting-edge technologies. The globe has recently seen the rise in popularity of the metaverse, a new digital technology. With an immersive experience, metaverse has as ability to effortlessly give patients and medical professionals a wide range of health services. This article suggests using blockchain technology with artificial intelligence in metaverse to provide patients a more realistic, quicker, and safer experience while receiving healthcare online. The essence of our suggested architecture is as follows. The metaverse's, patient's as well as the doctor's environment are the three environments that comprise this system. Blockchain technology helps to create a metaverse environment where patients and clinicians communicate while protecting patient privacy, security, and safety. The centerpiece of our suggested design is the environment of metaverse. Avatars are mediums for physicians, patients, and nurse representations in metaverse environment. These individuals join this environment via blockchain registration. These data are used by explainable artificial intelligence also called XAI algorithms to predict and diagnose illnesses. When it comes to the diagnosis and prognosis of illnesses, the GradCAM as well as LIME techniques of XAI provide confidence, explainability, interpretability, and transparency via logical reasoning. Thus, our suggested architecture provides openness and confidence for both illness detection and patient data protection. We also looked at the metaverse's key technologies.

Keywords Metaverse · Healthcare · Blockchain · Patient · Safety

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1 Introduction

Metaverse has garnered significant global interest and appeal in recent times. The metaverse is next stage of digital growth, with potential in order to drastically transform digital adoption and expand range of services beyond conventional online-accessible systems [1]. Over last several decades, trend of increasing effectiveness in commerce, leisure, and teaching and any other system that may be combined with internet access has been the digitization of services. The whole world is now moving forward to the metaverse, which allows people to connect the real and virtual worlds more immersively. Avatars being a digital representation of actual people into virtual world that may be used by the metaverse to accomplish a wide range of tasks [2]. With the use of metaverse technology, people may create a better real world while also creating a digital one. While "metaverse" as a word is not new, it has gained popularity in recent times. "Metaverse" was originally used in a book with fiction genre by "Snow Crash" author Neal Stephenson (1992) [3].

Meta means transcending, andverse refers to cosmos that describes a virtual world that is connected to real world. These two terms are combined to form the phrase "metaverse." Through virtual reality, augmented reality, XR or extended reality, as well as mixed reality, a convergence of technology which make it possible for the common population to engage digitally with virtual worlds while they are in real world [4]. In addition, metaverse is thought to become a network of immersive and virtual worlds where users may interact with avatars to create an immersive experience. The term "metaverse" refers to collection of emerging technologies which include blockchain, computer vision, robotics, AI, IoT and Internet of Things, cloud/edge computing, and robots. Artificial intelligence technology is used to create highly precise and accurate predictive systems, blockchain technology is used to build robust economic systems, and digital twin technology is combined to create a mirror image of actual or real world. Technology such as augmented reality makes a real and immersive experience possible [5]. The answer to combining all these relevant technologies in a global setting is the metaverse. For its prosumers, this idea generates a simulated digital environment that they may live in as an immersive virtual reality [6].

The metaverse is still in its infancy and is evolving all the time. Numerous businesses, including as medical, educational, agricultural tourism, networking sites, entertainment, and gaming, will benefit from the new prospects it will provide. Facebook, the massive social networking platform, altered its name to Meta in recognition of metaverse's potential, underscoring the significance of metaverse's. With the aid of the metaverse, the company's CEO is committed to bringing innovation to the corporate world. Gaming has also undergone a change thanks to the metaverse. Numerous businesses, including Epic Games Fortnite, have been using metaverse to allow users to enter a virtual environment and enjoy playing games digitally [7]. The metaverse has enormous potential for use across several areas of the economy, society, education, health, military, and government, even though it was created with the intention of extending social media's capabilities [8]. One well-known problem with remote

access as well as control systems is lack of an immersive experience. More innovation is needed, particularly when it comes to remote automation system which is based and created upon Programmable Logic Controller (PLC) or Supervisory Control and Data Acquisition (SCADA), fitting apparel, perception in architecture or commercial real estate, comprehension 3D visualization in the fields of architecture, engineering, alongside medicine; remote control of unmanned aerial vehicles (UAVs); enjoying two-dimensional multimedia experiences, and more. However, in the metaverse all of this will result in a more realistic and engaging online experience, improving our ability to communicate with our communities [9].

1.1 Rationale

Medical domain has an optimistic future in realm of metaverse, much as other domains. Metaverse has ample potential in order to capitalize on healthcare industry by enabling virtual medical and healthcare services via a full immersion experience driven by its remarkable features. Following the COVID-19 epidemic, there was a surge in demand for remote and non-in-person therapy. Furthermore, it has altered life's path in some manner. Nurse avatars are used to treat patients online these days. With wearable sensors, patient data, symptoms, and other relevant information are gathered. Avatars like Sensely and NHS interrogate people to get comprehensive data about them and their medical background. The models that are driven by blockchain and artificial intelligence process and evaluate the data. Physicians treat patients by using AI-powered models to provide feedback [10]. The metaverse healthcare environment is the result of the collaboration of many technical areas. The foundation of metaverse ecosystems includes technologies like blockchain, artificial intelligence, digital twins, fifth generation (5G) internet, and others. Compared to traditional systems, metaverse systems have a higher potential for collecting sensitive data, which presents a major risk to user privacy [11]. Private information in the metaverse platform, virtual world, or service system is very likely to be changed or compromised. They can also have virtual examinations with an immersive experience that mimics face-to-face interactions in the same setting. Benefits would be greater for homebound and disabled patients. Second, the metaverse provides rapid access to resources and services related to healthcare. As a result, patients' death rates from delays in receiving emergency medical treatment will decrease. Third, despite distance and travel difficulties, patients from rural locations with a physician and healthcare deficit are eligible to obtain benefits. Compared to traditional systems, metaverse systems have a higher potential for collecting sensitive data, which presents a major risk to user privacy. Private information in the metaverse platform, virtual world, or service system is very likely to be changed or compromised [12].

Finally, it lowers the number of patients visiting the clinic, reducing the transportation-related carbon footprint and assisting in the prevention of infectious illnesses and pandemics like COVID 19. It also lowers the cost of healthcare services. Fifth, without regard to location, metaverse provides seamless patient monitoring

functions using AR/VR technologies. Another and sixth is that, it helps patients feel less stressed and anxious [13]. It is used by medical professionals to practice difficult operations on simulated patients before attempting them on actual patients. Furthermore, metaverse technology is being used to cure phobias, mental health issues, and several chronic ailments. The purpose of this metaverse project is to prepare and create a framework for virtual therapy delivery in the metaverse by combining immersive technologies with cutting-edge technologies such as blockchain and artificial intelligence. This data concise several points:

1. In the field of healthcare, this article explores the possibilities of combining blockchain technology and metaverse with AI.
2. This paper illustrates the fundamental technologies of the metaverse and explains how they are used in metaverse healthcare.
3. This paper suggests using blockchain technology with explainable AI to diagnose and cure illnesses in a metaverse-based healthcare system.
4. Grad Cam and Lime approaches are utilized to assure explainability, while decentralized blockchain technology is employed to secure data security.
5. This report also lists the benefits and difficulties that metaverse presents for medicine and healthcare industry. [14]

The structure of this research project is as follows: The objectives is an overview of immersive metaverse, and possible advantages of applying it to healthcare are all covered. The relevant work on blockchain, AI, and metaverse is still being done and it is developing continously. The metaverse's foundational technologies and architecture are major part to be covered by the researchers. This chapter provide a detailed presentation of our proposed metaverse-based medicine and healthcare system's architecture. The pros as well as cons of metaverse are also mentioned [15].

1.2 Works Related to Metaverse

Metaverse technology is becoming more and more well-known every day, and it's thought of as the next development in digital technology. Every industry, including healthcare, entertainment, business, and education, might benefit from it. It's a fantastic technology that gives an immersive virtual world and integrates with other technologies. There are many relevant research efforts on metaverse technology, and academics are now concentrating on this new, developing technology [16]. Researchers have looked at how the metaverse functions in a variety of domains, including smart cities, e-commerce, healthcare, and education. Cardiovascular medicine based on metaverse was proposed. It was said to be CardioVerse. It had the ability to change as well as restructure the Herat and other cariovascular disease therapy process. It may also be used for a number of other purposes, including enhancing the accuracy and efficiency of cardiovascular therapies, disease prevention, and diagnostics. Blockchain and artificial intelligence integration in cardiovascular care was covered by researcher scholars. They went into more detail on the

possible uses and future paths of these technologies in the realm of cardiovascular illness. Additionally, they assessed the difficulties and looked into cutting-edge remedies for improved cardiovascular disease prevention and therapy. The metaverse has also been used in instruction and training. Over 200 surgeons saw this procedure live on television. The thoracic surgeons were outfitted with an immersive head-mounted display (HMD) and trained virtually. In the virtual setting, individuals may see the surgical procedures and take part in the conversation. Patients may obtain consultation, early diagnosis, individualized treatment, social prescribing, and patient education via wearable technology and avatars. The metaverse's gamification features may encourage individuals to take charge of their health and well-being [17]. A thorough evaluation of VR-based Parkinson's disease therapy was conducted by Desiderio Cano Porras et al. They did thorough and in-depth investigation and incorporated 97 research publications in their analysis. They came to a conclusion that few of the better ways to treat PK or Parkinson's disease is via immersive and VR-based rehabilitation. The significance of virtual reality-assisted treatment for many medical disorders was emphasized by Zhen Liu and colleagues. Virtual reality (VR) technology provide facilities remotely, circumventing the drawbacks of in-person conventional therapy. VR-based treatments became the most practical form of therapy for patients during COVID-19. The metaverse phenomenon and its effects on health and medicial were presented by Ali Garavand et al. They gathered information by using computerized searches to access renowned scientific databases like PubMed and Web of Science, among others. They came to the conclusion that the metaverse is rapidly growing in a number of healthcare domains, including medicine, medical procedures, medical imaging, etc. Scientists looked at potential and constraints of using the metaverse in teaching [18].

2 Metaverse Framework and Building Block

The Metaverse, a multidisciplinary ecosystem, is an online, three-dimensional space that integrates various technologies at different levels. To facilitate interaction between the real and virtual worlds, several elements work together, with customers being the most crucial among them. Users can engage with the virtual world using devices like head-mounted displays or AR/VR glasses, allowing them to perform various tasks. Other essential elements for real-world interaction include IoT networks, VSPs, and PSPs. Digital twins are created using data gathered from the real world through sensor networks and IoT [19].

2.1 Virtual Reality (VR)

Those who utilize virtual reality (VR) glasses or head-mounted display (HMD) may feel or experience a simulated environment. Using both technology and software, it

enables users to fully immerse themselves in 3D digital environment. Furthermore, it offers a flawless immersive experience together with cutting-edge technological capabilities. Granting users' freedom of moment in the virtual space While virtual reality technology is not a novel idea, its popularity increased with the introduction of the metaverse. In 2016, the amount invested in virtual reality companies was USD 2.3 billion; by 2025, it was anticipated to reach USD 20.9 billion. The major technology-based companies, including Samsumg, Apple, HTC, Google, Sony, and Meta (formerly Facebook), are working on VR gear like haptic gloves, optical trackers, 3D mice, and omnidirectional treadmills (ODts) for motion controllers. Gadgets offer incredible features. For instance, the Oculus Quest 2 is a virtual reality platform that has built-in CPUs. Numerous nations, including the USA, Japan, China, South Korea, and Taiwan, are concentrating on VR sector as crucial technological avenue with potential to strengthen economies overall. VR technology being utilized in medical and health field for a variety of procedures, including physical therapy, surgery, pain and stress management, and cognitive rehabilitation [20].

2.2 Extended Reality (XR)

All types of VR, AR, and mixed reality are included together under the name "extended reality" (MR). It encompasses every blended virtual as well as real settings. To create a realistic and engaging scene of discovery, it blends computer-generated aspects with ones from the actual world. AR projects digital material onto the physical world without generating a new environment, while VR immerses viewers in a completely virtual experience. The first-ever usage of the phrase "extended reality" occurred in 1960. Later on, almost every industry—including manufacturing, mining, healthcare, and education—uses this technology extensively. It provides an enormous number of levels in a virtual environment along with a wide range of applications and advantages. The haptic simulators are most widely utilized and used of these three technologies, and these are often used in patient procedures such as surgery [21].

2.3 Augmented Reality (AR)

Another technology that has changed how people see the world is augmented reality. AR enhances users' perceptions of the actual environment by blending fake items with digital overlays. To put it another way, augmented reality a process of adding digital elements to actual environment with help of superimposing digital pictures over it. Pokemon Go and other immersive games, which enabled us to view the world around us via our smartphones and superimpose digital characters, is major and one of the greatest instances of augmented reality. Similarly, we employ a variety of filters on Snapchat as well as Instagram for our posts on social media to enhance our

appearances, such as bunny ears, various makeup styles, etc. Augmented reality is a tool used by physicians and surgeons to help them during surgery by augmenting the area of the body that requires the operation. By overlaying genuine views of the surgery area with 3D photographs of patients, the visibility is improved. It accurately aids in the preservation of patients' lives. A few well-known augmented reality gadgets include the Magic Leap, Microsoft's HoloLens, and Google Glass [22].

2.4 Internet of Things (IoT) and Network

Internet of Things or IoT connects and enables communication between a vast array of objects, including smartphones, smart watches, medical equipment, and more, by using a variety of technologies including wireless networks, sensors and also nanotechnology. Internet of Things, with other technology, is simplifying the people's lives and changing how humans live. improves our quality of life as a result. It is commonly utilized in the medical and healthcare industry to provide doctors and patients with amenities. Through the use of various IoT devices, patients may be remotely monitored, improving overall quality of treatment and lowering expenses. The metaverse ecology also depends heavily on this technology. The integration of IoT technology enhances the metaverse's potential. Virtual service providers will benefit from IoT devices incentives to collect and sense physical state of items, which aids in the synchronization of digital twins [23].

2.5 Edge/Cloud Computing

In the period of technological advancement edge computing is the novel idea wherein computations are carried out at the network's edge. The goal of this is to provide computer services nearer to source of the data. Every day, more and more data being generated due to the expansion of edge devices and the Internet of Things. This comes with a number of issues, such as energy use, data security and privacy, and delays in real-time operation. Edge computing is novel computing mode which operates closer to the edge of network devices, was presented as solution to some of the problems. It enhances data optimizing, privacy and security, and current businesses [24].

2.6 Artificial Intelligence (AI)

The well-known technology known as artificial intelligence (AI) has found use in a wide range of sectors, including enterprises, manufacturing, agriculture, healthcare, and human resources. With artificial intelligence, computers may replicate

human cognition and learn from experiences in a similar way to humans. Experience allows it to carry out a variety of jobs. Artificial Intelligence comprises several subfields such as natural language processing, machine learning, computer vision as well as deep learning. Three types exist within machine learning, one of the broad fields of AI: reinforcement learning, unsupervised/unmonitored learning, and supervised learning. While the unsupervised learning and also reinforcement learning are utilized for the unlabelled data and supervised learning requires labelled data for the model's training. Neural networks that are modelled after biological neurons are used in the machine learning discipline of deep learning. Features are extracted from the data via depth or deep learning. In addition, it requires a lot more data than traditional machine learning. The primary technology that will propel the growth, support, and enable the realization of the metaverse concept is maorily AI. Artificial intelligence (AI) techniques, such as computer vision, deep learning, reinforcement learning, and machine learning, are "key" in bridging the gap between both worlds which are physical as well as virtual one. Artificial intelligence enables metaverse to engage in social and economic activities outside of an actual world in safe and unrestricted manner [25].

2.7 Digital Twin

An electronic copy of a physical object is called a digital twin. A digital replica of the real objects is created in the virtual world. It is being used to a number of sectors, including as smart urban areas, healthcare, and even in manufacturing. The primary three elements of this technology are the real item, its digital or virtual equivalent, and the data connection connecting the two. The use of digital twins was critical to the healthcare sector during the COVID-19 pandemic. Medical personnel were able to digitally monitor patients while keeping an eye on their vital indications, such as heart rate, blood pressure, as well as temperature, by using wearable technology, such as smartwatches and smartphones [26].

2.8 Computer Vision

The computer can perceive and observe things thanks to computer vision. It makes it possible for the extended reality devices to recognize and comprehend visual data from the physical world, which helps to generate virtual worlds. The reconstruction of 3D things and objects in the cyberspace is a major use of this technology in AR/VR and XR. Computer vision-based techniques are being employed in the metaverse to create a 3D immersive experience that is better and more accurate for users. With the newest techniques as Yolo, Mask R-CNN which deep learning methods, computer vision can accurately execute identification of objects, classification, segmentation, and location of the objects. Because avatars must identify and

understand the behaviours of other people's avatars, computer vision may also be used for action recognition as well as gesture recognition two more crucial parts of the metaverse [27].

2.9 Blockchain

One of major and essential technologies which makes ecosystem inside metaverse unbeatable is blockchain technology. For the first time, Nakamoto Satoshi introduced blockchain in 2008. A distributed ledger, also referred to as a blockchain, is made up of successive blocks that are connected to each other and each carry the hash value of block header before it. It uses digital signatures and a decentralized network to store data. Information that has been saved will not be liable to alter or change. In financial industry blockchain is prominent, but that may also be applied in many other fields, including social services, risk management, healthcare, and education. Blockchain tech in metaverse may be used in healthcare to protect patient privacy. Hence improving the patient record's security. Patient data cannot be changed or removed once it is saved on the blockchain. It also facilitates the management of electronic health information and offers patients quicker, less expensive treatment. Additionally, it offers tools for data interchange, data security, integrity, and interoperability. With enhanced network security, blockchain tech controls all interactions between real and virtual worlds. To maintain track of them, all of the exchanges are likewise documented. This blockchain feature makes it easier for physicians to review and comprehend patient's health and medical history [27].

3 Avatar

"Avatar" is a Hindi term refers to appearance of the Hindu deity in the material world as either a person or an animal. Humans exist in the metaverse as virtual avatars, which are replicas of real people. Users have an ability which can alter the looks and appearance of their avatars to suit their own preferences. A scene from an advanced game, like PlayerUnknown's Battlegrounds or Fortnite, are common examples. Avatars have been used in the medical field to teach physicians, nurses, and other healthcare workers as well as to monitor and treat patients. Surgeons can do complex surgery more easily because it makes virtual environments more visible. The Designed Structure of the Healthcare Metaverse Fueled by Blockchain (BC) and Explainable Artificial Intelligence (XAI) This section outlines our suggested healthcare metaverse framework [28].

Blockchain and artificial intelligence are the driving forces behind this design. The architectural framework consists of three distinct environments or realms:

(i) Doctor's or practitioner's environment

(ii) Metaverse environment
(iii) Patient's environment

The primary goal of this project is to seamlessly provide patients immersive virtual health experiences with the use of blockchain technology and artificial intelligence. Thanks to cutting-edge technologies like blockchain, metaverse, and artificial intelligence, it is now feasible to virtually provide excellent medical services while also diagnosing and performing difficult medical operations. Metaverse technology provides access to counseling and other healthcare services for patients [29]. Artificial intelligence technology is integrated for illness diagnosis, prognostication, and patient state monitoring. Additionally, the AI-based model helps physicians carry out intricate treatments with the least amount of mistake. Regarding the particular instance of a medical surgical process, the AI-based model enables annotations and segmentation, which aid the surgeons in superimposing their hands on the damaged area, hence increasing the procedure's accuracy. Blockchain technology is utilized for patient data acquisition, storage, and transmission to guarantee data security since it prevents data alteration and abuse by other parties. Additionally, it fosters patient confidence while facilitating traceability and transparency. Both the patient and the physician are given an ID so that they may preserve their medical records, trace their identification, and be individually identified [30, 31].

3.1 Doctor's Environment

Physicians or doctors enter and integrate into this milieu from a distance. XR tools are used by the doctor to interact with the virtual world, and all type of the records are kept onto blockchain. Doctor must first register in order to be given an ID, which is then saved on blockchain and used to interact with virtual environment. When doctor enters that immersive environment, a block that represents a transaction is produced [32, 33].

3.2 Patient's Environment

There will eventually be healthcare facilities in the patient's surroundings. For the patients' treatment, these institutions have cobots, nurses, and caretakers. A patient must go through the registration procedure before requesting treatment. The blockchain will be used to store the registration data. After assessing the patient's medical state, a caregiver is matched with them. Using VR equipment, the patient will use their ID to enter the virtual world [34, 35].

3.3 Metaverse Environment

Since all healthcare services will be delivered digitally in this environment, the metaverse environment makes up the majority of the whole design. In this setting, avatars of physicians, nurses, and patients are constructed. Through one other's avatars in the metaverse, the doctor and patient start the consultation procedure [36]. Natural language processing (NLP) is used to extract data from voice recordings made during the consultation process. The patient will give the necessary laboratory test results from the specialists if more information about the patient's condition is needed after the NLP data has been analyzed, such as image data from CT or MRI scans or other clinical data. For instance, if a patient has lung illness, the doctor may ask the patient for a chest CT or MRI from a radiologist. The information (MRI or CT scans) supplied by the radiologist will be added to the patient's blockchain and made available to the doctor. Following data gathering, we evaluate the acquired data for predictions using a pre-trained AI model. The usage of explainable artificial intelligence (XAI) techniques, such as LIME/GradCAM, varies based on the nature of the intervention (surgical process) or the kind of data (image data). With the use of XAI, medical professionals may clearly identify the elements contributing to a patient's illness [37]. Furthermore, by offering a logical justification for the forecast, the explainable artificial intelligence based model will guarantee the model's trustworthiness, explainability, interpretability, and transparency. The aforementioned output is accessible in both the metaverse and the surroundings of the patient and clinician. Following the diagnosis, the patient receives appropriate treatment. When a certain scenario arises, as during a surgical procedure, a cobot is required, and the patient's surroundings are given instructions on how to do the surgery [38]. The real-time movement of physicians towards the cobots is captured by a gesture recognition module; real-time OT setup and video monitoring complement this process. The artificial intelligence technology process in our suggested design is shown in Algorithm 1. Images and CSV formatted data are gathered from various surroundings in Algorithm 1. The GradCAM/LIME is used by the artificial intelligence-based model to assess the data and provide a forecast. The black box character of the AI models is addressed by this method. It guarantees the model's explainability and transparency [39, 40]. Medical practitioners might utilize the AI model's output to make judgments about difficult surgeries and treatments, resulting in a more immersive experience. The information flow on the blockchain in our metaverse is shown in Algorithm 2. In Algorithm 2, the system looks for the most appropriate and available physician when a patient seeks a consultation. Patients' information is collected from the blockchain if they have previously registered with the metaverse healthcare facility; otherwise, they must go through the registration procedure. The patient has a caregiver assigned to them. Moreover, the smart contracts for the patient and caregiver will be carried out. The patient's request for treatment must be approved by the doctor by signing the request if the doctor is accessible and his expertise satisfies the patient's demands. The doctor's smart contract will go into effect upon his or her signature. The virtual

environment that IDVEnv detected will be the starting point for the treatment procedure. Following the course of treatment, the environment is deleted and the output of the XAI is uploaded to the blockchains of the corresponding environments [41, 42].

4 Metaverse Healthcare Advantages and Challenges

The medical community has long understood how important it is to engage with patients physically on a regular basis in order to assess their mental and physical well-being [43]. Nevertheless, this process has been blatantly interrupted by the COVID-19 epidemic, leaving medical professionals unable to come up with any other ideas. Although the metaverse has many advantages, there are several challenges as well. In this section, we elucidate some of those advantages and challenges [44].

4.1 Advantages of Metaverse in Healthcare

4.1.1 Health Monitoring

By using AI-based tech in the metaverse, patients may keep an eye on their health without physically visiting a hospital or scheduling doctor's visits. The security and effectiveness of healthcare services in the metaverse may also be increased with the usage of blockchain technology. It may provide a distributed ledger that is safe to store private information, including medical records. Smart contracts may also make it possible for insurers and providers to make automatic payments without the need for human processing or outside middlemen [45]. In the field of physical health, scholarly investigations have mostly focused on interventions aimed at improving individuals' physical capabilities and alleviating discomfort. The results of the study demonstrate favorable outcomes in several domains, including balance, posture, gait, power, and cognition enhancements. Nevertheless, there were none significant enhancements seen in terms of physiology and psychology. A significant number of virtual reality applications used for rehabilitation and fitness reasons adopted a gamified methodology [46].

4.1.2 Education in an Immersive Environment

The Metaverse may revolutionize how individuals are taught by giving augmented reality as well as other virtual features in order to assist learning in stressful environment and conditions. With virtual reality technology, patients might be able to have virtual consultations with physicians or other medical experts in a dreamlike setting [47]. This might lead to change from standard study books to an interactive 3D instruction at virtual institutions. With the limits of present virtual education

systems highlighted by Corona virus (Covid-19) epidemic, technology employed in the Metaverse provide opportunity to enhance educational systems [48].

4.1.3 Surgeries in a Virtual Environment

Understanding anatomy is an important part understanding how our body works both regularly and improperly. But anatomy education has changed as a result of technology, and we now have the convenience of metaverse applications to assist us in this process. Since holographic simulations allow for immersive learning experiences, such as understanding the relationship between smoking and lung cancer, they have the potential to be used in medicine. They also help in teaching difficult medical and clinical skills, such as endoscopic surgery. Intelligent diagnosis and therapy are also made possible by the use of artificial intelligence technology, which helps to handle clinical issues. With the development of metaverse technology, medical professionals may now operate virtually with great precision and less inaccuracy from human error [49]. Metaverse may also be used for surgical training. Via a metaverse, the Seoul National University Bundang Hospital provided education and interactive training in pulmonary cancer surgery. More than 200 surgeons obtained this training. The 3D holographic image gives extensive information on individual bodily parts, eventually leads to deeper knowledge of human anatomy. Professors and doctors have the option in order to customize models, frameworks and textual labels, that may be stored for use in future [50].

4.2 Challenges of Metaverse in Healthcare

4.2.1 Application Development

Given that metaverse is a multidisciplinary platform, it interacts with a diverse array of different tech, like blockchain, network-based computing, edge computing, networking, augmented reality, virtual reality, XR, AI, avatars, and 3D representation of every item. Consequently, creating a metaverse environment that can provide a dreamlike experience is a difficult undertaking. High proficiency, resources, and talents are required. All of the technologies should work together seamlessly and effectively [51].

4.2.2 Data Privacy and Security

Due to the fact that the whole physical world is digitalized and replicated in the metaverse, metaverse is extremely susceptible to data confidentiality and security concerns. One crucial component of the metaverse ecology is data protection. Thus, safeguarding the metaverse ecology from any hazards is a significant obstacle. User

privacy, including geographic privacy, behaviors, habits, and so forth, may be jeopardized while engaging in digital life in the metaverse [52, 53]. This is because data services life cycle includes data understanding, processing, transmission, governance, and keeping. There might be dire repercussions if hackers target the metaverse-enabling technologies, such as Meta Quest and the Oculus helmet. Since most healthcare IoT systems rely on centralized methodologies, there are a number of possible data security risks. Their resilience and security are compromised by issues such a single point of failure (or breach) and purposeful or unintentional record tampering. Studies, however, have revealed a number of other privacy and security concerns. Blockchain technology is unmatched in its ability to provide medical information security and confidentiality. Many experts concur that blockchain technology is a viable defense against the vulnerabilities present in IoT-based health systems. Numerous intrinsic properties of blockchain include provenance, trust, immutability, decentralized applications, and transparency [54, 55]. Blockchain's characteristics provide healthcare data with unbreakable security. Several scholars have proposed a variety of methods based on blockchain to protect healthcare IoTs and data. For instance, some studies also unveiled a novel architecture for the healthcare IoT systems are built on fuzzy logic and blockchain technology that ensure privacy and fast response capabilities. They propose a behavior-driven adaptive security solution for blockchain-based networks and healthcare IoTs by utilizing fuzzy logic. Additionally, they provide a heuristic approach to behavior-centric security adaptation that provides services for audit logs, authorization, and authentication (AAA). They combined blockchain technology with online privacy machine learning. They were able to improve the healthcare system's resilience and security because to this strategy [56].

4.3 Trusts

People are not very confident in the healthcare metaverse since it's still in its initial stages and metaverse is still evolving as well as growing. Instead of relying on holographic AI-based systems and avatars, people do believe in physicians. By raising the standard of metaverse medical services, therapies, and diagnostic tools, the gap in patient confidence with the metaverse should be bridged. Technologies like explainable AI and blockchain contribute to increased user trust [57]. Due to its distributed and irreversible nature, blockchain offers the greatest solutions for data protection and transparency. Patients are the owners of their data in the healthcare industry and have greater faith in these platforms. It would be difficult to hack into or tamper with their medical records. Additionally, because physicians will be held responsible for the prescriptions they write because treatment history on blockchain is clearly traceable, also unchangeable, it also reduces medical carelessness on their part. In the end, it increases confidence and promotes openness. In addition to blockchain technology, a patient-centric engagement policy contributes to increased patient trust [58].

5 Conclusions

The worldwide healthcare and clinical market in metaverse is expected to be valued 71.97 billion US dollars by the year 2030, with significant room for growth. This offers an opportunity to transform industries, improving accessibility, cost-effectiveness, and client support. The emergence of the metaverse is going to offer fresh chances for creativity and development in the medical field. The fundamental technologies that form the foundation of the metaverse ecosystem include digital twins, blockchain, 5G, virtual reality, and artificial intelligence. Despite being presented as the solution to all future digital growth, there are practical concerns and obstacles surrounding the metaverse. Most essential problem is absence of a functioning digital network which can supply required services as well as apps which have ascribed computing and communication abilities. Even while such an infrastructure does exist, the access tech needed to provide the desired requirements can be achieved only with the yet-to-be-deployed, experimental 5G mobile technology. Before launching the metaverse, the interoperability and compatibility between the real as well as virtual worlds must be established. Given the potential and scalability offered by the social-media backbone, it is obvious that resources would not be sufficient to meet the demand even with an intimidating level of processing power at metaverse engines. Therefore, in order to have an economic way of handling, storing, networking, and finance, the best processing and operating techniques must be used. Our research project suggests a blockchain-based metaverse ecosystem for medical services that uses artificial intelligence.

Implementing the AR, VR, and XR applications, the patient and physician leave their separate domains and enter the metaverse environment. Physicians and patients may have better immersive virtual experience in metaverse healthcare setting. Physicians and patients communicate with one another, create knowledge, and share it digitally via avatars. Patients would get a variety of medical services in the metaverse/virtual hospital setting, including therapy, counseling, surgery, and counseling. Patient data will be fed into explainable artificial intelligence (XAI) based frameworks for examination, projection, and health condition identification. Logical cause and forecast of disease will be given by the XAI models.

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Metaverse Enabled Entertainment and Gaming Information Systems: A Systematic Review

Ananya Mishra and Pradeep Kautish

Abstract To better comprehend the trends in the literature on the metaverse, entertainment, and gaming information systems, this study employs a systematic literature review technique. It also makes recommendations for potential avenues for study to further the area. This study reviewed 74 publications about metaverse, entertainment, and gaming information systems using the theory-context-characteristics-methodology (TCCM) paradigm and related documents published in Scopus and Web of Science (WoS) and used the SLR technique because it comprises an objective, transparent, and repeatable process that maximizes data and reduces bias by gathering all pertinent and available evidence on a given subject. This study is exceptional because it (1) examining the study features, research environments, applied theories, and methodologies employed in earlier studies to provide a cutting-edge comprehension of the metaverse, entertainment, and gaming information system literature; and (2) suggests the limitations which future researchers can utilize the opportunity for the field to advance. By identifying these gaps, the study contributes to a better knowledge of the state of the field and acts as a springboard for more research aimed at filling in these gaps and advancing the field. In the end, this research's conclusions have the potential to significantly advance innovation and advancement in the quickly developing area by improving and fine-tuning gaming and entertainment systems in the metaverse. The findings will contribute to and improve the entertainment and gaming systems that are enabled by the metaverse and assist researchers in concentrating on understanding regions in this diverse field.

Keywords Entertainment · Interactive games · Metagames · Immersive games · Systematic literature review

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1 Introduction

An experience occurs when a company intentionally uses a service as the platform and practical items as props to engage with certain clients in a way that customers a memorable event [28]. The idea of offering an entertainment experience is becoming more and more popular these days, even in places other than theatres and theme parks. New technologies in particular are creating whole new experience genres: motion-based simulators, online chat rooms, virtual reality, multiplayer games, and interactive games [41]. Experiences that most people associate with entertainment-such as watching television, going to a concert, or participating in some other activity-usually include customers participating more passively than actively; their connection to the event is more likely to be one of absorption than immersion [28]. Demand for the products and services provided by the computer industry is currently being driven by the desire for experiences that are ever-more immersive due to the growing processing power required [7]. The entertainment sectors use a lot of metaverse technology to provide their audience and customers with distinctive experiences. The fundamental flaws in web-based 2D and 3D across a range of businesses in entertainment can be addressed via the metaverse [8]. Social media systems based on metaverse allow businesses to interact with their audience, craft experiences that are specifically catered to them, and use data to discover businesses that can benefit from their goods and services [35].

The history of online video entertainment is full of examples of how the industry has responded quickly to opportunities that continue to arise as a result of technological developments, notably in transmission speeds. Before broadband became widely available, online video entertainment was first experimented with by a flurry of mostly defunct content providers in the in the mid-to-late 1990s. Examples of these companies include Icebox.com, Atomfilms.com, Ifilms.com, and Entertainmentdom.com [17, 21]. Despite being established in the mid-1990s, online video entertainment continues to evolve in terms of content, revenue streams, and market dynamics. These changes have been primarily caused by dramatic technological advancements, the rapid adoption of broadband Internet from 3% of households in 2000 to nearly two-thirds of households just 10 years later- and the growing preference of consumers for online media delivery over offline media.

The "Global Entertainment & Media Outlook 2023–2027" study by PricewaterhouseCoopers projects that India's entertainment and media sector would grow at a 9.7% compound annual growth rate (CAGR) to reach $73.6 billion by 2027 [29] and currently India is expanding at a 20% annual rate, making it the fifth largest market in the world [39]. Some of the key growth drivers are OTT platforms, the gaming sector, online and out-of-home advertising, and gaming [31].

The practice of "gaming", or playing video games, or competing in them, is now referred to as eSports. Within the world's fastest-growing sector, this is a very important topic. Some reports assert that a threefold of the global community "plays" video games, despite the fact that video games themselves are phenomena dependent on the demand for play [4, 36]. Video games have grown from a hobby to a big market

in the entertainment sector all at once. The market for video games was evaluated in 2023 and was estimated to be worth 197.11 billion dollars. By 2025, however, estimates place the industry's value at 268 billion dollars 51 [15].

A new era of immersive experiences and limitless possibilities has been brought about by the integration of Metaverse into the constantly changing world of digital entertainment and games [25]. Through the seamless integration of virtual and physical worlds, these advanced systems surpass traditional limitations, providing users with previously unheard-of levels of engagement and interactivity [24]. Users can connect with other gamers, explore huge landscapes, and take part in engaging narratives in richly detailed worlds with futuristic technologies like computer-simulated reality and mixed reality [1, 14]. Furthermore, the incorporation of blockchain technology guarantees safe transactions and virtual asset ownership, promoting a healthy economy in these virtual domains.

The interest in metaverse-enabled entertainment and gaming information systems is currently receiving an abundance of focus from scholars and professionals in a variety of areas, including smart education, gaming development, content creation and narrative, and so forth [10, 12]. These studies have applied numerous ideas both conceptually and practically, and they have also covered a range of antecedents and outcomes of metaverse in gaming and entertainment. Th results of these investigations, meantime, have been very dispersed, despite the fact that novel ideas and conceptions have produced a multitude of insightful information about the topic.

Academic researchers find it challenging because this phenomenon is fragmented, to determine hypotheses and quantify important aspects related to it across multiple subfields. After doing a thorough systematic literature review (SLR), our work aims to close this gap and offer a comprehensive understanding of the metaverse in entertainment and gaming information systems. The study is specifically guided by the subsequent research questions (RQ):

RQ1. How is metaverse-enabled entertainment and gaming information system conceived and measured in the literature?

RQ2. Which theories are proposed to describe the procedure of metaverse-enabled entertainment and gaming information systems?

RQ3. Which significant antecedents and outcomes have been researched in order to comprehend metaverse-enabled entertainment and gaming information systems?

2 Review Approach and Structure

We decided to use the SLR technique because it comprises an objective, transparent, and repeatable process that maximizes data and reduces bias by gathering all pertinent and currently accessible data regarding on a given subject [40]. Additionally, researchers use the SLR to investigate integrative frameworks that incorporate existing knowledge. To find pertinent research articles from reputable journals, robust criteria must be followed [26].

We utilized the theory, context, characteristics, and methodology (TCCM) framework developed by Paul and Rosado-Serrano [27] among other forms of SLR. TCCM is a reliable technique during SLR that groups theory, context, characteristics, and methodology in an understandable and categorized manner and also it provides avenues for additional breadth and aids in filling in the gaps found in previous research [33].

We conducted the SLR using the methodology Paul and Criado [26] recommended. In the initial stage of identification, define, and prepare the study's research questions. Creating the screening and assessment criteria for the literature was a part of the second and third phases. The data coding and outcome analysis comprised the fourth phase and the concluding was the last phase. Sub-sections that follow provide a detailed explanation of the SLR methodology used in this work.

2.1 Defining the Scope and Definition of Metaverse-Enabled Entertainment and Gaming Information Systems

Selecting the area to perform the SLR was the first stage in the review process. The entertainment and gaming information systems may grow in the future due to the potential of the metaverse-enabled generation, but the literature on it showed that the context of entertainment and gaming information systems has not much been explored.

In this study, metaverse offers an unprecedented degree of personalization, immersion, and interactivity in the entertainment sector as it has been greatly impacted often known as virtual reality worlds, which have created avenues for immersive encounters and interactive storytelling [35].

2.2 Article Search and Selection Process

As per [40], the selection of studies for this SLR was based on three inclusion criteria. Initially, Scopus and WoS repositories were chosen as the search boundary due to their extensive coverage of business journals and frequent usage by other recent SLRs [46]. Second, the search formula was ("immersive AND games") OR ("interactive AND games") OR ("creative AND games") OR ("metaverse AND games") OR ("entertainment AND in AND ai") OR ("3d AND games"), which currently appeared in an article's keywords, abstract, or title. In order to make sure the search yields as many relevant records as possible. After searching for each keyword we selected the articles which were related to our area of research. The final condition concerned the duration of the papers; we didn't restrict the duration of our search but rather set a termination point of the end till 2024. After searching, as a final source of the review study, 74 articles were selected.

2.3 Data Synthesis and Analysis

This research stage involved manual data evaluation, with our data adequately compiled using MS Excel. We used the form for extracting data created by Zupic and Cater [45] to provide an update the practical features of the articles, methodology, gaps, theories, antecedents or consequences, significant findings, and future directions. Through data extraction, we were able to create a comprehensive overview of the methodological features, research boundaries, and all sample publications.

3 Descriptive Analysis

We present our findings on publication patterns in this area. The metaverse in entertainment and gaming literature's TCCM, research fields, publication sources, year of publication, and keyword analysis are all included in the analysis. The gaps in the literature that need further study in the future will be identified with the use of this analysis.

3.1 Year of Publication

It is obvious that the review's oldest research is from 2002, given that metaverse, entertainment, and gaming are still in their early stages of research. The rate at which pertinent knowledge was created between 2002 and 2019 was sluggish. Only 16% of all studies were published in throughout this period. On the other hand, the number of studies increased significantly between 2020 and 2024. In addition, the fact that 34% of all articles published in 2021 were. published in 2021 indicates the expansion of the metaverse-enabled entertainment and gaming industry in recent years.

3.2 Research Fields and Publication Outlets

The majority of the articles that made up our analysis were published in journals in field of computer science (n 30, 60%), and the remaining 40% were published in journals in field of management, sports, sustainability, tourism, ethics, etc. This variety serves as an example of how metaverse in the context of entertainment and gaming study is interdisciplinary. The research was published in 16 distinct ABDC journals, according to a detailed examination of the article's distribution. Among these 16 journals, some of the journals were Journal of Managerial Psychology, Journal of Marketing Management, Journal of Hospitality and Tourism Technology, Journal

of Brand Management, Journal of Managerial Psychology, Journal of Industry and Innovation, and Journal of Creativity and Innovation Management.

3.3 Keyword Analysis

Through the use of keyword occurrence analysis, research might uncover hidden links or emergent themes between different conceptions. The co-occurrence network map makes it easier to quickly identify the important topics in the literature by analyzing the title, abstract, and keywords of each study [3]. The 74 articles since the sample were subjected to a keyword retrieval and analysis process using the VOSviewer software.

The figures' co-occurrence network diagram illustrates the connection in among the various keywords and themes. The themes are represented by the more noticeable nodes, while keywords are represented by the smaller nodes that link the themes. There is an inverse relationship between co-occurrence and node distance, which means that the more the co-occurrence, the shorter the distance. The size of the node shows how often a keyword appears [13].

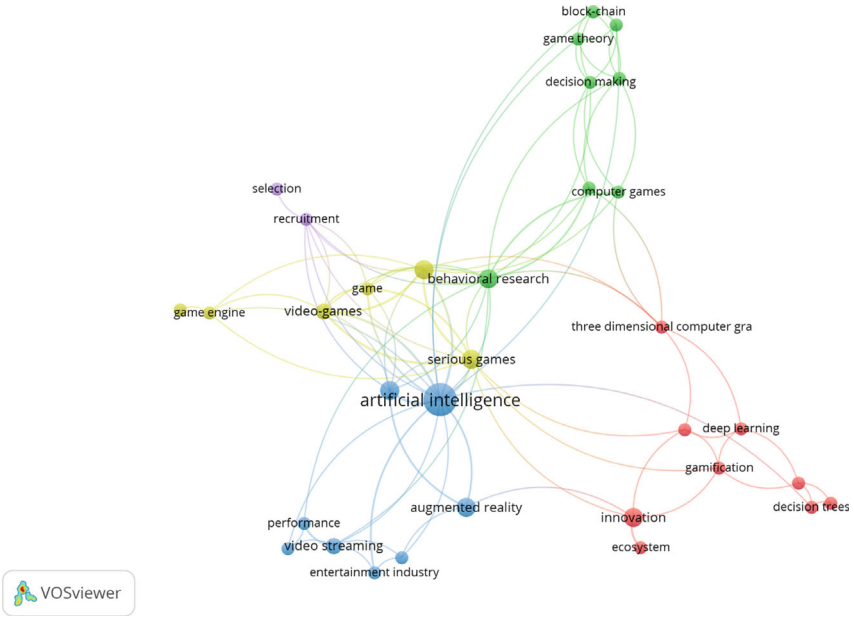
The theme one, with blue, had papers with "artificial intelligence" as the primary keyword,, as was to be expected. These investigations were primarily associated with other keywords like "augmented reality", "virtual reality", "video streaming", "entertainment industry", "performance", and "user experience". The user experience and performance stand out since it can give the user a conspicuous consuming experience. For example, the industry may now anticipate customer preferences and tastes ahead of time because of recent advancements in AI technology. Managers can use this data to personalize each customer's consumption experience, which increases the perceived value of the entertainment and gaming information system and, eventually, the positive behavioral intentions of consumers.

Theme two in yellow consisted of papers with keywords such as "video games", the game engine", "game", "serious games", and "human–computer interaction". Video game players perceive and accept value systems from the games, which influence how the games are played. A real video game human computer interaction is achieved by focusing on video game values, which encourage a holistic perspective of video games as software, media, and as games especially [38].

Theme three in green consisted of papers with keywords such as "behavioral research", "computer games", "user behavior", "decision making", "game theory", and "blockchain". These publications emphasized how the metaverse, in conjunction with blockchain technology and video games, may elicit strong feelings of emotion and pleasure. This theme emphasizes meeting these needs by offering metaverse experiences, as taking this action is a prelude to forward-looking consumer responses to the games, considering that customers often look to fulfill their needs as per their decision-making, which reflects in their behavior through adaptation of metaverse.

Theme four in red as "innovation", "three-dimensional computer games", "gamification", neutral networks", "online games", and "ecosystem".

The last theme in purple consisted of the keywords “selection”, and “recruitment”.



4 Theory, Context, Characteristics, and Methodology (TCCM) Framework

It integrates theoretical foundations, study contexts, antecedents and outcomes, to highlight and contextualize key discoveries about entertainment and gaming information systems.

4.1 Theoretical Foundations

In the subsequent subsections, we discuss the top theories and mechanisms applied in the literature.

4.1.1 Affordance Actualization Theory

Several scholars have The theory originated by James J. Gibson who defined affordances as “action possibilities” [11]. The goal-oriented behaviors that actors perform

as they use technology to attain an objective are referred to as affordability actualization theory" [6, 34]. Many academics have looked at affordance actualization theory, which originated in ecological psychology, as a useful framework for understanding the change allowed by information technology [47]. It has been applied to numerous domains, including engineering [23], education [5, 9], and human–computer interaction (HCI) [37].

4.1.2 Game Theory

A theoretical framework known as "game theory" is applied to comprehend and explain scenarios in which decision-makers must communicate with one another [44]. The application of game theory to studies of technology dissemination has grown [22], for instance, used game theory to examine how stakeholders decide which IoT platforms to use in projects involving prefabricated building, [43] in their study investigated the best ways for construction companies to implement BIM and the best government subsidy plans.

4.1.3 User and Gratification (U&G) Theory

This theory has been used in many studies to comprehend user motivation for usage across a range of platforms, such as social media, the internet, online gaming, and mobile social gaming. It was initially introduced by Kaur et al. [48], and offers a method for comprehending a new media landscape through a how-and-why analysis of media consumption [30]. The theory changes its focus from the traditional [46, 47] media effects theory's media-centered view of how transmitters utilize media to what receivers do with media [42]. There are five guiding concepts of U&G theory: First, media consumption is purposeful. Second, viewers actively influence the media that they see and consume. Third, to meet different demands, the media competes with alternative sources. Fourth, viewers understand that media outlets compete with one another to meet different demands. Fifth, the importance of media content and the satisfaction derived from media consumption can only be evaluated by the audiences themselves [2, 16]. Recently, U&G theory has proven vital in assisting with the understanding of how people use and are interested cutting edge technologies like augmented reality [32], virtual reality [18], and artificial intelligence [19].

4.2 Research Contexts

The research on the "metaverse" has evolved, having first surfaced with relation to video games and entertainment and then spreading to several industries, including wireless systems, education, and even road maintenance systems. Several studies have been encompassed to bridge the gap separates the real and virtual worlds, the

metaverse has been studied as a platform for social interactions, content exchange, and immersive experience, its training potential, integration with IoT technologies, and use in secure smart city creation have also been investigated. Blockchain technology has also been employed within the metaverse for digital asset management. Issues with addiction and criminality have also been explored by highlighting how crucial it is to comprehend the societal ramifications.

4.3 Study Characteristics

4.3.1 Antecedents

Out of 74 studies, user happiness in information systems is influenced by several factors, including system utilization, user computer knowledge, hardware and software accessibility, availability, and attitude. Virtual environments, metaverse trust (MET) Metaverse financial resources (MEF), and immersive games is seen as antecedents of the metaverse.

4.3.2 Outcomes

The majority of the 74 articles were concerned with the metaverse-enabled entertainment and gaming information system outcomes in establishing frameworks for researchers in AI, usage of AI in gaming, designing of digital platforms via AI, and in the context of AI support for the proposed connections between adopting an AI-powered avatar and the psychological effects on customers.

4.4 Methodology

To determine the study methodology (qualitative or quantitative), sample parameters, and analytic technique(s) employed, we examined 74 distinct papers.

4.4.1 Research Approach

Of the 74 research papers, 55 (74.3%) used qualitative research, while 19 studies (25.7%) employed a quantitative approach. In-depth interviews, focus groups, case study analysis, and observations were used in qualitative studies. Surveys followed by experiments were the most common methodology used in quantitative studies. The ethnography method was employed in one article. According to these findings, researchers employed interpretive methods in qualitative research and conventional

research procedures in empirical research which is consistent with the majority of previous studies in the virtual reality.

5 Discussion and Implications

In order to analyze the current state of metaverse use in the entertainment and gaming industries and to gain a better understanding of how it has evolved over time, the study set out on a methodical journey. Our study highlights the complex structure of the discourse by carefully analyzing and synthesising the body of existing literature. It does this by exposing a landscape that is full with different viewpoints on contextual details, character dynamics, theoretical frameworks, and methodological techniques. With the help of the strong TCCM (Theory, Context, Character, and Methodology) framework, our efforts aims to bridge these divides by providing a thorough synthesis of results. More than just providing light, our work aims to stimulate the development of the virtual reality industry by putting forth focused interventions that seek to uncover uncharted territory. We propose a careful examination of latent problems in the field of virtual reality, including theoretical boundaries, ontological features, methodological paradigms, and contextual arrangements, all of which are carefully scrutinized under the prism of the TCCM paradigm. This paper offers a comprehensive review of the existing literature by carefully selecting 74 articles from prestigious journals published by the Australian Business Dean Council (ABDC). It also acts as a lighthouse, shedding light on the state of knowledge regarding metaverse-enabled gaming and entertainment systems. By using advanced bibliometric analysis, we were able to identify key contributions and the academic strongholds that shaped the conversation. As a result, researchers now have essential knowledge to help them purposefully and clearly traverse this rapidly developing subject. This enlightenment helps to clarify the fundamentals of the metaverse and provides a path forward for future research that sites at nexus of creativity, discovery, and academic integrity [20].

6 Limitations of the Study

There are various drawbacks with this study, just like any other explorations. First, we extracted data from WoS and SCOPUS; the results might have been different if we had used different sources. We could verify and expand on our findings with the help of other database sources. Second, we did not included books nor dissertations. These documents could be used by researchers to look into various facets of the metaverse in relation to gaming and entertainment information systems. Third, there are only 74 papers in the collection, thus it's possible that some relevant papers were overlooked. Fourth, the study may have benefited from the application of additional analyses such as co-authorship analysis and bibliographic coupling. These might have offered some

intriguing and in-depth perspectives on the published works in the field of virtual reality. Fifth, the study's carefully thought-out definition may restrict the keywords that can be used. The established criteria have been used to determine the keywords, even though the researcher's judgement is exercised during the keyword selection process. However, further directions may exist that the study might have failed to notice. Therefore, more research might be needed to find additional directions based on a more comprehensive analysis; the first step would be to broaden the keyword search. Notwithstanding all of its limitations, this study offers a thorough analysis in the area of gaming information systems and metaverse-enabled entertainment, and it establishes the standard for future researchers to follow in expanding their studies in the same direction.

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Development of Digital Cultural Tourism Contents for the Caves of India, a UNESCO World Heritage Site Using AR-Bus

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Abstract Digital cultural tourism, coupled with the advancements in augmented reality (AR) technology, has emerged as a powerful tool for enhancing visitor experiences at heritage sites worldwide. This research aims to develop and implement AR-Bus technology for the Caves of India, a UNESCO World Heritage Site, to enhance visitor experiences and promote cultural heritage preservation. The study involves creating the AR-Bus prototype and conducting user testing to provide an immersive and educational journey through the caves. Through storytelling, interactive elements, and real-time information, AR-Bus offers visitors a unique and enriching experience, fostering a deeper appreciation for the historical and artistic significance of the Caves of India. This innovation represents a significant advancement in cultural tourism, providing a novel way to explore and understand these ancient wonders.

Keywords UNESCO World Heritage Site · Digital cultural tourism · Caves of India · Augmented Reality (AR) –Bus · Extended Reality (XR)-Bus · Media-Bus · Artificial Intelligence Bus

1 Introduction

The Caves of India hold immense historical and cultural significance, making them a UNESCO World Heritage Site. These caves, scattered across the country, are a testament to the rich heritage and artistic prowess of ancient civilizations. These

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caves, located across various regions of India, showcase intricate rock-cut architecture, exquisite sculptures, and vivid murals. Dating back centuries, they serve as a window into the rich cultural and religious heritage of the subcontinent. From the majestic Ajanta and Ellora Caves to the stunning Elephanta Caves, each site holds its own unique story and charm.

Despite their historical significance, the caves face challenges in terms of proper preservation and promotion. Factors like natural weathering, human intervention, and limited accessibility can hinder the overall experience for visitors. As a result, there is a need for innovative approaches to preserve and promote the cultural heritage of the caves.

During the COVID-19 pandemic, most countries across the globe implemented a ban on travelling to control the spread of the virus. This decision had significant adverse effects on the tourism industry [1]. With restrictions on international and domestic travel, hotels, airlines, and other related sectors experienced a sharp decline in bookings and revenue. The global tourism industry faced unprecedented challenges as tourists cancelled or postponed their plans due to uncertainty and health concerns.

After the COVID-19 pandemic, it is expected that there will be a significant increase in technology development and implementation within the realm of digital cultural heritage [2]. The crisis has highlighted the importance of digitizing cultural artefacts and making them accessible online for virtual education, research, and tourism purposes. Museums, libraries, and other cultural institutions have been forced to adapt to the new normal by embracing digital technologies such as augmented reality (AR), virtual reality (VR), 3D scanning, and artificial intelligence. Additionally, there is a growing demand for digital preservation strategies to safeguard cultural heritage in the face of potential future disruptions. As a result, professionals working in this field are now focusing on innovative ways to enhance digital experiences for audiences worldwide while preserving and promoting our rich cultural legacy.

The primary objectives of studying Development of Digital Cultural Tourism Contents for the Caves of India, a UNESCO World Heritage Site using AR-Bus bus is to enhance visitor experiences, promote cultural heritage preservation, and increase accessibility to these historical sites. By utilizing augmented reality technology, researchers aim to create immersive and interactive content that educates tourists about the significance of these caves while also providing a unique and engaging way to explore them. Additionally, implementing digital technologies can help in showcasing the rich cultural history of India's caves to a global audience, fostering appreciation, and understanding of their importance. Through this study, professionals in the field seek to harness the power of digital tools to revolutionize cultural tourism experiences and contribute towards sustainable heritage management practices.

1.1 Digital Cultural Tourism

Digital cultural tourism is like taking a virtual vacation to explore the rich heritage and cultural wonders of different places without leaving your couch. It is all about using

digital technology, such as websites, mobile apps, and virtual reality, to experience and learn about different cultures, historical sites, art, and traditions.

Digital cultural tourism has evolved alongside advancements in technology. In the past, we relied on guidebooks and brochures to plan our trips and learn about the destinations we wanted to visit. But now, with just a few taps on our smart phones, we can access a treasure trove of information and immersive experiences that bring cultural tourism to life.

Digital cultural heritage offers many advantages in preventing the destruction of cultural sites due to environmental factors, mass tourism, and urbanization [3]. Digital cultural tourism is important because it allows people from all corners of the world to connect with and appreciate diverse cultures. It promotes understanding, fosters cultural exchange, and can contribute to the preservation and conservation of heritage sites and traditions.

1.2 Augmented Reality (AR) Technology

Augmented Reality defined as "an environment that includes both virtual reality and real-world elements [4]. Augmented Reality (AR) technology has revolutionized the management and preservation of cultural heritage by offering immersive and interactive experiences to engage audiences in a new way. Through AR, historical sites, artefacts, and cultural objects can be digitally reconstructed and brought back to life for study, education, and preservation purposes. AR allows users to overlay virtual content onto the real world, enhancing visitors' experiences by providing additional information and context about historical sites, artefacts, and artworks [5].

Virtual Reality (VR) is an advanced, human–computer interface that simulates a realistic environment. The participants can move around in the virtual world [6]. VR immerses users in a fully simulated environment, blocking out the physical world and replacing it with a computer-generated one. Users typically wear a headset equipped with sensors to track their movements and interact with the virtual space. On the other hand, AR overlays computer-generated images on top of the real world, blending digital content with the physical environment. AR enhances the user's perception of reality by adding contextual information, such as directions or additional visual elements. While both technologies share similarities in creating immersive experiences, their key difference lies in how they interact with reality: VR creates an entirely new digital environment, whereas AR enhances the existing physical world [7].

AR is a perfect match for cultural tourism. It can provide visitors with contextual information, stories, and multimedia content that enhance their understanding and appreciation of cultural sites, artefacts, and artworks [8]. With AR, cultural tourism becomes a dynamic and immersive journey, enabling visitors to connect deeply with the cultural heritage of a place.

Fig. 1 **a** Hwangryong AR Experience Zone **b** User's experiencing AR Technology

1.3 The Limitations of Existing Cultural Heritage AR

There have been many attempts to utilize augmented reality (AR) for cultural heritage in the past. However, compared to virtual reality (VR), there are several limitations that have been revealed. Firstly, the real-time object registration technology of AR is not satisfactory [9]. For example, the registration between the object to be augmented and the computer-generated (CG) image displayed on the AR display is not consistent. Secondly, the screen size is too small. Most people use smart phones or tabs to experience AR services. However, due to the limitations of screen size, viewers do not get an immersive experience in the field. Finally, the hardware performance of smart phones or G tabs limits the graphic quality of the 3D objects to be augmented, resulting in poor AR effects [10]. For these reasons, cultural heritage tourism using augmented reality has not been very effective over the past 20 years. On the other hand, AR-Bus can solve all the shortcomings of conventional AR (Fig. 1).

2 Literature Review

2.1 O-World Zoo- the (Mixed Reality) MR-Bus

Mixed reality (MR) is a subset of virtual reality (VR) technologies that focuses on the seamless integration of real-world elements into virtual environments, creating an immersive experience that blurs the lines between the physical and digital worlds [11]. In 2019, Daejeon, a vibrant city in South Korea, introduced a unique and innovative way to explore the renowned O-World Zoo - the MR-Bus Safari [12]. Equipped with panoramic windows and advanced audiovisual systems, the MR-Bus offers passengers a breathtaking 360-degree view of the zoo's diverse wildlife. As the bus navigates the park, visitors can interact with virtual animals, learn about their habitats, and even hear their distinctive sounds. The MR-BUS technology adds

Fig. 2 Exterior of the Zoo MR Bus

Fig. 3 Snapshot of MR Bus

an extra layer of excitement and engagement, making the safari experience truly unforgettable.

The MR-Bus technology provides a barrier between visitors and the animals, ensuring both parties are kept safe. The virtual aspect of the experience also reduces the risk of accidents and allows for controlled interactions, minimizing any potential harm to the animals or visitors (Figs. 2 and 3).

2.2 Suwon Hwaseong City (Extended Reality) XR-Bus

Extended Reality (XR) is a term used to refer to the immersive technologies of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies combine elements of the physical world with computer-generated enhancements, creating entirely new digital experiences [13]. XR goes beyond traditional reality by allowing users to interact with both physical and virtual elements simultaneously, blurring the lines between what is real and what is digital. The Suwon Hwaseong city XR-bus [12] offers a captivating and immersive experience for visitors exploring the UNESCO World Heritage Site of Hwaseong Fortress in Suwon, South Korea.

Fig. 4 Exterior of the XR Bus

Fig. 5 A Snapshot of Suwon Hwaseong

From historical narratives to interactive exhibits, the XR-bus tour takes visitors on a journey through time, allowing them to engage with the architectural marvels and significant events of Hwaseong Fortress in a whole new way. From touchscreens providing additional information to 3D models of historical artefacts that you can virtually inspect, there is something for everyone to get up close and personal with Suwon's rich heritage.

In a world where attention spans are dwindling, preserving our cultural heritage is more crucial than ever. The Suwon Hwaseong XR-bus shows how technology can become an invaluable tool in engaging and educating visitors about the past. By making history interactive, immersive, and accessible, XR technology breathes new life into our ancient stories and helps us connect with our roots (Figs. 4 and 5).

2.3 UNESCO World Heritage Tourism XR-BUS

This time, we would like to introduce the UNESCO World Heritage Tourism XR bus in Gyeongju, Korea [14]. Tourism XR buses are a promising new technology that can provide passengers with more information and immersive experiences in the site. There are more than 10 UNESCO World Heritage Sites in Gyeongju. Korea

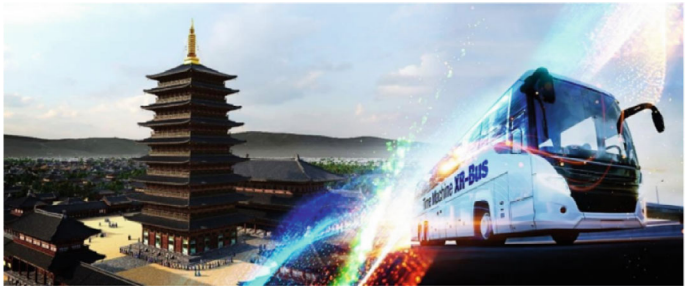

Fig. 6 Gyeongju UNESCO World Heritage Site AR Bus

Gyeongju XR bus is a kind of package digital tourist product that travels around these UNESCO ruins. This will go beyond traditional urban tour buses and create new trends in digital tourism. It will be possible to give tourists a new digital experience for cultural heritage. Lastly, this will be a great help in understanding the cultural heritage and history of Gyeongju (Fig. 6).

The literature review highlights several innovative applications of MR-Bus and XR-Bus technologies in enhancing visitor experiences at various cultural heritage sites, such as zoos, fortresses, and UNESCO World Heritage Sites in South Korea. However, despite the extensive discussion on the effectiveness of these technologies in providing immersive and educational experiences, there is a notable research gap regarding their adaptation and implementation specifically for cave environments, particularly within the context of UNESCO World Heritage Sites. While MR-Bus and XR-Bus have been successfully utilized to showcase wildlife, historical narratives, and architectural marvels, there is limited exploration of how similar technologies, particularly AR-Bus, could be adapted to the unique characteristics and challenges of cave environments to enhance visitor engagement and understanding of the cultural heritage preserved within cave systems, such as those found in the Caves of India. Therefore, this study aims to address this research gap by investigating the development and utilization of digital cultural tourism contents using AR-Bus technology specifically designed for cave environments, ultimately enhancing visitor experiences and appreciation of the cultural significance of the Caves of India UNESCO World Heritage Site.

The development of augmented reality (AR) technology has opened new possibilities for enhancing cultural tourism experiences, particularly in historically significant sites such as the Caves of India, a UNESCO World Heritage Site. While existing research has explored the use of AR buses in various cultural contexts like zoos and historical fortresses, there exists a notable research gap when it comes to the specific application of AR technology in the Caves of India. These ancient rock-cut caves, with their intricate sculptures, paintings, and architectural marvels, present a unique cultural context that demands a modified approach to AR content development.

Research is needed to understand how AR can contribute to the preservation efforts while providing an engaging and educational experience for visitors. Additionally,

the integration of AR with the caves' features, such as highlighting specific paintings and explaining their historical significance, remains largely unexplored. The potential for AR to simulate original colors and textures of the artworks could greatly enrich the visitor experience and understanding of the site's history.

Another critical aspect is the need for accessibility and inclusivity in AR-based tourism. While AR offers immersive experiences, ensuring that these experiences are accessible to all visitors, including those with disabilities, requires focused research. Developing AR features such as audio descriptions, tactile feedback, and multilingual support can make the Caves of India more accessible to diverse audiences. Moreover, community engagement through AR initiatives could empower local stakeholders to contribute to the development of AR content and storytelling, fostering a sense of ownership and stewardship towards the site.

Here addressing the research gap in the application of AR technology for the Caves of India could lead to the creation of innovative and inclusive experiences for visitors. By focusing on preservation, integration with cave features, accessibility, and community engagement, AR has the potential to breathe new life into these ancient wonders, making them more engaging and accessible to a global audience while ensuring their conservation for future generations. Further research in these areas will not only enrich the tourist experience but also contribute to the long-term preservation and promotion of this UNESCO World Heritage Site.

3 AR-Bus Technology

Introducing AR-Bus, the innovative solution that brings together the convenience of guided tours with the magic of augmented reality. AR-Bus is a state-of-the-art system that integrates AR technology into a dedicated tour bus. Equipped with AR-enabled windows, visitors can witness virtual reconstructions of the caves and their historical context as they traverse the surrounding landscapes. This unique blend of travel and technology offers an unparalleled and unforgettable experience.

The distinction between conventional AR-Bus and MR-Bus or XR buses is primarily centred around the concept of augmentation. In the case of MR-Bus or XR Bus, there is almost no interaction. Exports general computer graphics images in fragments. In contrast, AR-Bus enables the audience inside the bus to engage and interact with Ellora Grottoes located across from the bus and it enhance passenger experience and provide useful information during the journey.

3.1 Evolution of AR-Bus Technology in Tourism

AR-Bus Technology has evolved significantly over the years, transforming traditional bus tours into immersive and engaging experiences. Initially, bus tours provided audio commentary or printed guides, but with advancements in technology, augmented

reality has revolutionized the way tourists explore new destinations. By incorporating interactive elements and virtual guides, AR-Bus Technology has taken tourism to a whole new level of excitement and enjoyment.

3.2 Benefits of AR-Bus

AR-Bus technology offers several advantages over traditional tourism approaches. It allows for personalized and interactive experiences, catering to the diverse interests and preferences of visitors. It also overcomes physical limitations, making it accessible to a wider audience. Moreover, AR-Bus offers real-time translations, audio guides, and interactive storytelling, enhancing the overall visitor experience and facilitating cultural understanding.

4 Components of AR-Bus

The Augmented Reality (AR) System designed for the augmented reality bus of Ellora Caves presents an innovative fusion of technology and historical exploration. Within this innovative system, various components work in harmony to transport passengers on a captivating journey through time and culture. At the heart of this experience is the Translucent Screen Window, a portal that links the physical confines of the bus with the virtual world of the Ellora caves. Here, passengers can interact with vivid AR content, including detailed 3D models, historical information, and navigation guidance. Complementing this window to the past is the AR Content Module, a repository of knowledge that provides passengers with a wealth of information about the caves. This module brings history to life through an Information Database, 3D Model Renderer, and Navigation System, creating an immersive and educational experience. These components, alongside the Computer System with its powerful processing capabilities and essential AR Libraries, form the backbone of the AR system, while the Sensors Module captures real-world data for accurate AR overlays. Enriching this experience further is the Audio System, offering narrated audio guides and ambient sounds synchronized with the AR content. Finally, the Power Supply ensures uninterrupted operation; ensuring passengers can delve into the wonders of the Ellora caves without interruption. Together, these components form an innovative design blending historical context with technology, offering passengers a unique and immersive journey through the ancient marvels of Ellora.

4.1 Translucent Screen Window

The Translucent Screen Window serves as the primary interface for users to interact with the augmented reality (AR) content displayed within the bus. A Translucent display has been mostly used for AR device [15]. This component features a high-resolution display capable of showing detailed 3D models, historical information, and navigation guidance related to the Ellora caves. The Screen Display subcomponent ensures that AR visuals are presented clearly and vividly to passengers, enhancing their experience. Touch Sensors integrated into the window enable intuitive user interaction, allowing passengers to select points of interest, navigate through the caves virtually, and access additional information with a simple touch. This component is pivotal in providing an immersive and educational AR journey for passengers, bridging the gap between the physical environment of the bus and the virtual world of Ellora caves.

4.2 AR Content Module

The AR Content Module acts as the brain of the augmented reality system, responsible for curating and delivering a rich array of information about the Ellora caves to passengers. Within this component, Information Database stores historical details, facts, stories, and other educational content related to the caves. The 3D Model Renderer is tasked with creating realistic and detailed 3D representations of the caves and sculptures, offering passengers a visually captivating experience. Additionally, the Navigation System provides interactive guidance, allowing users to explore the caves virtually and discover points of interest along the way. These subcomponents work seamlessly together to ensure that passengers receive a comprehensive and engaging AR experience, blending historical knowledge with interactive exploration.

4.3 Computer System

The Computer System serves as the computational powerhouse of the AR bus, handling various tasks essential for the system's operation. The CPU, GPU, and RAM components collectively process AR data, ensuring smooth rendering of 3D models and seamless interaction with AR content. AR Software within the system executes applications that create and manage the AR experience, including rendering visuals and handling user inputs. Crucially, the Computer System also includes AR Libraries such as ARKit, ARCore, Vuforia, Wikitude, and Unity 3D with AR Foundation. These libraries giving new opportunities to create immersive applications and games [16]. These libraries provide the necessary tools and frameworks for AR

development, enabling functionalities such as object recognition, tracking, and interaction logic. The Computer System's role is fundamental in translating raw data into a compelling and interactive AR journey for passengers aboard the bus.

4.4 Sensors Module

The Sensors Module is responsible for gathering real-time data essential for creating an accurate and immersive augmented reality experience. Included in this module is a GPS Receiver, which provides precise location data for location-based AR content [17]. The Accelerometer and Gyroscope components detect motion and orientation [18], ensuring that AR overlays and interactive elements align correctly with the physical movement of the bus. Cameras are used to capture these images and then the virtual world is augmented with these captured images. Hence, the quality of the camera has significance in creating a realistic environment along with the 3D modelling and rendering process [19]. Cameras equipped with image processing capabilities capture the real-world views outside the bus, enabling AR content overlay with the environment. To make the world more realistic, it is augmented by mixing the real-world object and scenes. These sensors work to provide the AR Content Module with the necessary information to render contextual and location-aware AR content, enhancing the overall immersion and accuracy of the experience.

4.5 Audio System

The visuals may seem the most important feature of the AR, VR, or XR virtual environment, audio might be the most developed one [20]. The Audio System adds another layer of immersion to the AR experience by providing audio guides and ambient sounds synchronized with the AR content. An Audio Database stores narrated information about the caves, which is triggered based on the user's location and interaction within the AR environment. The Audio Player component plays back these audio guides, offering passengers a narrated tour of the Ellora caves as they explore virtually. Additionally, the Audio System generates ambient sounds such as birds chirping or water flowing, creating a more immersive and lifelike environment within the bus. This component enriches the AR journey with auditory cues, complementing the visual and interactive aspects for a multi-sensory exploration of Ellora caves.

4.6 Power Supply

The Power Supply component is the backbone of the AR bus system, ensuring continuous operation of all components by providing a steady and reliable source of electricity. The Power Distribution Unit manages and distributes power to each component, preventing interruptions and downtime during the AR experience. Without this component, the entire AR system would not function, emphasizing its critical role in maintaining the immersive journey for passengers. By supplying power to all components, the Power Supply enables a seamless and uninterrupted exploration of the Ellora caves through augmented reality, allowing passengers to delve into history and culture while onboard the bus.

5 Research Methodology

5.1 Research and Data Collection Process

The development of digital cultural tourism contents for the Caves of India involves an extensive research and data collection process. Firstly, the research involves an extensive literature review of existing AR-based tourism applications, particularly focusing on those related to heritage sites and cultural tourism. This includes studying historical records, archaeological findings, and consulting with experts to gather accurate and comprehensive information about the caves' cultural significance. This review helps in understanding the technological advancements, best practices, and potential challenges in implementing AR technology for cultural preservation and tourism.

The methodology includes on-site data collection at the Caves of India. This involves capturing high-quality images, 3D scans, and videos of the caves and their surroundings. These data serve as the foundation for developing accurate and detailed digital replicas of the caves, artefacts, and historical elements using AR technology.

5.2 Designing Interactive AR Content for AR-Bus

Designing interactive AR content is where the real magic happens. With the help of advanced technology, we can bring the cave art and history to life through augmented reality. This includes creating 3D models of the cave paintings, animations that depict their creation process, and interactive elements that allow visitors to explore and learn at their own pace. The goal is to strike a balance between entertainment and education, ensuring that the experience is both enjoyable and informative.

5.3 User Testing and Feedback Collection

This phase involves conducting pilot tests of the AR applications with actual visitors to the Caves of India. Feedback and insights gathered from these tests are used to refine and improve the applications, ensuring they meet the needs and expectations of users.

5.4 Collaborative Efforts with Archaeological and Cultural Experts

Developing digital cultural tourism contents for the Caves of India requires close collaboration with archaeological and cultural experts. Their insights and expertise ensure the accuracy and authenticity of the digital representations. By working together, a more holistic and engaging experience can be created for visitors, preserving the cultural heritage of the caves for future generations.

6 Implementation and Integration

6.1 AR-Bus Infrastructure and Equipment

Implementing AR-Bus Technology requires the installation of appropriate infrastructure and equipment on buses. This includes interactive screens, audio systems, and GPS tracking devices, which enable the seamless delivery of augmented reality content to passengers throughout the tour (Fig. 7).

6.2 Integration with Mobile Applications and Devices

To enhance the tourist experience, AR-Bus Technology can be integrated with mobile applications and devices. This allows tourists to access additional information, maps, and real-time updates related to their tour. By leveraging smart phones or tablets, visitors can engage with augmented reality features and easily navigate their way through the destination.

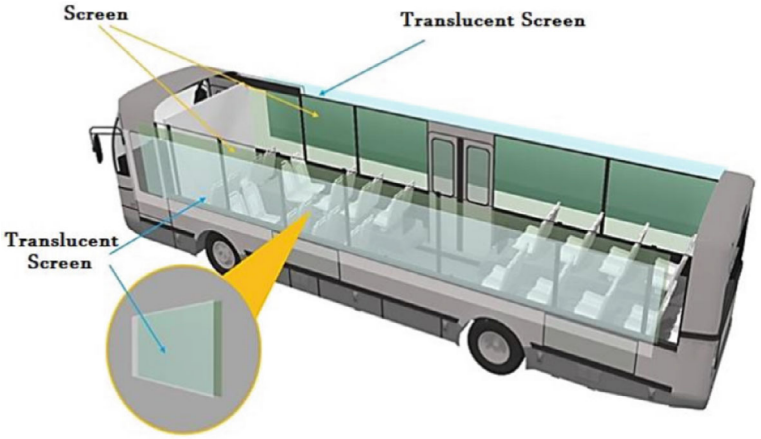

Fig. 7 Proposed AR-Bus

6.3 Training and Support for Staff and Tour Guides

To ensure a smooth implementation of AR-Bus Technology, adequate training and support must be provided to the staff and tour guides. They need to be well-versed in operating the technology, troubleshooting any technical issues that may arise, and offering assistance to tourists who may require help during the augmented reality experience.

7 AR-Bus at the Caves of India

The AR-Bus experience at the Caves of India takes visitors on an immersive storytelling journey. By combining virtual elements with the physical surroundings, we create a narrative that transports visitors back in time, allowing them to witness the creation of cave art firsthand. The interactive nature of the experience facilitates a deeper understanding and emotional connection with the art, making the visit truly unforgettable (Fig. 8).

Beyond entertainment, the AR-Bus at the Caves of India offers significant educational benefits. Through carefully crafted interpretive approaches, visitors can learn about the historical context, cultural significance, and artistic techniques employed in the caves. The interactive nature of the content encourages active learning and fosters a sense of curiosity and exploration. By providing a dynamic and engaging educational experience.

Fig. 8 Sample AR-Bus for Ellora Caves

8 Interaction Between AR-Bus Passengers and Ellora Caves

The basic goal of augmented reality is to create a virtual reality in the real world. In the case of the AR-Bus, when it stops at a section of the Ellora Caves, the current appearance of the Ellora Cave, which is seen as a conductor, must be reflected and the effect of adding virtual to it is required to become an AR-Bus. Furthermore, passengers on the bus will be able to communicate with the Ellora Caves outside the bus through interaction solutions such as hand gestures or buttons.

9 Discussion

The proposed AR-Bus technology for the Caves of India offers a unique and transformative approach to cultural tourism, particularly when compared to existing models like the MR-Bus and XR-Bus. While these technologies have shown success in various heritage sites, the specific adaptation of AR for cave environments, especially at UNESCO World Heritage Sites like the Caves of India, remains largely unexplored.

A key advantage of our AR-Bus concept is its ability to provide an immersive, interactive, and personalized experience for visitors. By showcasing intricate cave art, historical narratives, and cultural significance in detail, AR-Bus goes beyond traditional tours, offering a dynamic journey through the caves. This approach addresses a significant gap in existing models, where visitors may not have the opportunity to engage deeply with the historical context and stories behind the cave art.

Inclusivity and accessibility are also crucial aspects where AR-Bus excels. The integration of Braille inputs and audio descriptions allows visually impaired individuals to engage with the AR content, making the Caves of India more accessible to a

wider audience. This emphasis on inclusivity is a notable improvement over existing models, where accessibility features may be limited or non-existent.

Our research contributes significantly by showcasing the potential of AR technology in creating tailored and immersive experiences for cave environments. By integrating historical context, interactive elements, and educational content, AR-Bus enhances visitor understanding and appreciation of the cultural significance of the Caves of India.

This study also addresses limitations in the existing literature on cultural tourism technologies. While MR-Bus and XR-Bus have been effective, their focus on general computer graphics and lack of interactive engagement with historical sites are notable gaps. AR-Bus aims to bridge these gaps by offering a more comprehensive and inclusive experience for visitors.

The innovative AR-Bus technology for the Caves of India represents a significant advancement in digital cultural tourism. Its comparison with existing models, emphasis on accessibility, and potential to enhance visitor engagement highlight its importance. By integrating AR technology into the exploration of the Caves of India, we enhance visitor experiences while contributing to the conservation and accessibility of these historical wonders for future generations.

10 Conclusion

The development and implementation of AR-Bus technology for the Caves of India, a UNESCO World Heritage Site, present a transformative approach to cultural tourism. The Caves of India stand as a testament to the rich history and cultural heritage of ancient civilizations, showcasing remarkable rock-cut architecture, intricate sculptures, and vibrant murals. However, these historical sites face challenges such as limited accessibility, natural weathering, and the need for preservation.

The COVID-19 pandemic underscored the importance of digital technologies in cultural preservation and tourism, leading to a surge in innovations like augmented reality (AR). This study aimed to fill a research gap by exploring the adaptation of AR technology specifically for cave environments, focusing on enhancing visitor engagement, understanding, and accessibility to the Caves of India.

Through an extensive literature review, it was evident that MR-Bus and XR-Bus technologies had successfully enhanced visitor experiences at various cultural heritage sites. However, the specific application of AR-Bus technology in cave environments, particularly for UNESCO World Heritage Sites like the Caves of India, remained unexplored. This research sought to address this gap by developing and testing AR content tailored for the unique characteristics of these caves.

The methodology involved rigorous research, data collection, and collaboration with experts to ensure the accuracy and authenticity of the AR content. Designing interactive AR experiences allowed visitors to engage with 3D models, animations, and historical narratives, providing a deeper understanding of the cave art and history.

User testing and feedback collection helped refine the AR applications to meet the needs and preferences of visitors.

The implementation of AR-Bus technology required the installation of infrastructure on buses, integration with mobile applications, and training for staff and tour guides. The AR-Bus experience at the Caves of India offers a captivating journey through time, blending virtual elements with the physical surroundings to create an immersive and educational experience. Visitors can interact with virtual reconstructions of cave art, learn about historical contexts, and explore the caves in a unique and engaging way.

The proposed outcomes of this research include the development of interactive AR content showcasing 3D models, animations, and historical information of the Caves of India. This content will be integrated into the AR-Bus technology, providing visitors with an immersive and educational tour experience. The implementation of AR-Bus infrastructure and equipment on buses will allow for the seamless delivery of augmented reality content throughout the tour. Integration with mobile applications will offer additional information and real-time updates to enhance the visitor experience. Moreover, the training and support provided to staff and tour guides will ensure they are equipped to operate the AR technology and assist visitors during the AR-Bus journey. Finally, user testing and feedback collection will be conducted to refine and improve the AR applications, ensuring optimal engagement and learning outcomes for visitors exploring the Caves of India.

The innovation of this research focus on adapting AR technology specifically for cave environments within UNESCO World Heritage Sites, such as the Caves of India. By combining historical accuracy with interactive storytelling, this approach offers a unique and immersive educational experience for visitors. The topic of digital cultural tourism using AR-Bus technology is of wide practical applicability, not only benefiting tourists but also contributing to the preservation and promotion of cultural heritage sites around the world.

In conclusion, the AR-Bus at the Caves of India represents a significant advancement in digital cultural tourism, contributing to the preservation, promotion, and accessibility of this UNESCO World Heritage Site. By leveraging AR technology, the Caves of India can be brought to life for a global audience, fostering appreciation and understanding of India's rich cultural heritage. This innovative approach not only enhances tourism experiences but also ensures the conservation and sustainability of these ancient wonders for future generations to explore and cherish. As we continue to navigate the evolving landscape of cultural tourism, AR-Bus technology stands as a beacon of innovation, offering a bridge between the past and the present for all who seek to explore the wonders of the Caves of India.

11 Future Work

11.1 Advancements in AR-Bus Technology

The future of AR-Bus technology in tourism looks promising, with ongoing advancements in the field. As technology improves, AR experiences will become more seamless, realistic, and interactive. This includes the development of more sophisticated AR headsets or smart glasses that could enhance the user experience, making it even more immersive and engaging.

11.2 Integration with Other Emerging Technologies

Integration with other emerging technologies, such as artificial intelligence and machine learning, will further enhance the capabilities of AR-Bus technology. For example, AI-powered language translation can enable tourists to receive real-time translation of audio or visual content during their bus tours, breaking down language barriers and making tours more accessible to a global audience.

11.3 Integration of AI Digital Human

With the integration of AI digital human, tourists can now engage with intelligent virtual assistants, enhancing their overall journey and providing personalized information and assistance (Fig. 9).

Then, in detail, we would like to suggest how to combine AI digital human beings with XR buses. Historical figures related to the site appear. This person guides the ruins through the deputy manager on the XR bus. It will be much more effective than

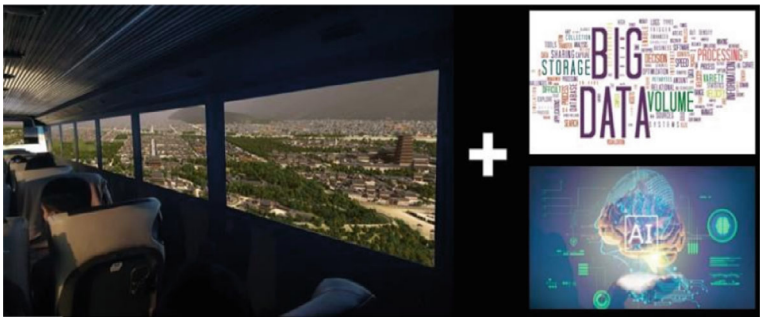

Fig. 9 Big data -based AI digital human XR bus

one -sided narration description. However, the AI digital human, which guides the ruins, must be related to the site. The general actor character should not appear. It should be a person who is related to the ruins of storytelling shown on the XR bus. For example, XR buses showing Indian caves must be a technician who made the cave, or a king of Indians related to the cave. Especially important is that if AI digital human appears, Q & A can be done with the audience. In the case of the XR bus AI digital human, the construction of Big Data is very important. This is because you can communicate with the audience based on Big Data.

To this end, the expansion of big data that AI digital human can express is very important. In the end, AI can move with enough Big data.

AI digital humans are the friendly and knowledgeable guides that accompany tourists on their AR-Bus journeys. These virtual beings, powered by AI and advanced speech recognition technology, interact with passengers, provide information, and answer queries. They can showcase historical figures, act as language interpreters, and offer recommendations based on individual interests, making the entire experience more personalized and engaging.

11.4 Addition of Smell, One of the Five Senses, to AR-Bus

Previously, VR and XR only focused on sight and hearing, but did not pay attention to the important sense of smell. To experience cultural heritage in the future, research on olfactory experience using AR technology is needed.

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Building Blocks of the Metaverse: Exploring Virtual Environments

S. Mahalakshmi, H. Bharath, and Sandeep Kautish

Abstract "Building Blocks of the Metaverse: Exploring Virtual Environments" explores the fundamental components that form the metaverse's many landscapes. A thorough introduction to virtual environments is given in this chapter, along with an analysis of their purpose, design, and place in the larger digital world. The chapter starts out by explaining what virtual environments are. They are described as immersive online areas where people may connect and participate with artificial surroundings. The evolution of virtual environments is examined, with a focus on the transition from simple text-based systems to the complex, multi-dimensional worlds of modern metaverses. The main elements of virtual environments—graphics, audio, and interaction—are at the center of the conversation. The chapter examines how cutting-edge technologies like mixed reality (MR), augmented reality (AR), and virtual reality (VR) might improve the immersive experience in these virtual worlds. The chapter also looks at the many types of virtual environments, such as business conference rooms, social centers, and gaming settings. It describes the unique attributes and capabilities of every environment, clarifying their individual goals and user interactions. Furthermore, the chapter discusses the design concepts and factors that must be taken into account when developing virtual environments, placing a strong emphasis on the value of scalability, accessibility, and user experience. The discourse delves into the significance of procedural generation and user-generated content in promoting dynamic and ever-changing virtual environments. "Building Blocks of the Metaverse: Exploring Virtual Environments" ultimately emphasizes how important virtual environments are as the core components of the metaverse, influencing how people communicate, work together, and become fully immersed in digital experiences. This chapter provides insightful information about the complex

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web of virtual worlds that make up the metaverse through a thorough examination of its architecture and operation.

Keywords Metaverse · Virtual reality (VR) · Augmented reality (AR) · User interaction · Accessibility · Ser interaction

1 Overview of the Metaverse Concept

Digital consumption is becoming more and more prevalent, resulting in a fundamental shift in consumer patterns. Globally, for instance, customers report that interacting with brands via internet platforms is simpler for the [1]. At the same time, companies are investing a far higher percentage of their profits in digital environment support systems. Combining these elements will create a highly favourable environment that will contribute to the "metaverse," a hyper-connected digital universe that has the potential to develop into a seamlessly interconnected virtual reality space that will drastically alter how customers, brands, and businesses operate. The metaverse is seen by many as having the ability to revolutionize social and corporate interactions on par with the Internet (Bobier et al. 2022).

In 1992, Neal Stephenson's novel Snow Crash coined the term "metaverse," describing a black, spherical world that people could reach using computers equipped with built-in virtual reality features and where they might appear as avatars (Stephenson 1992). Thirty years later, the made-up idea of the metaverse has progressively developed into a legitimate commercial factor for marketing purposes, among other uses [2].

The term "metaverse" first surfaced in computer science literature in the 1990s, in relation to research on virtual humans, interactive environments, and real-time autonomous agents [3]. In this context, the metaverse was understood to be a cyberplanet or quasi-physical virtual reality environment where users were portrayed as avatars. This perspective aligns with the notion of the metaverse seen in early fiction literature as well as the definition provided by Davis et al. [4], who characterized metaverses as "immersive three-dimensional virtual worlds in which people interact as avatars with software agents and each other (Stephenson 1992). The metaverse was later defined as "an extensive 3D networked virtual world capable of supporting a large number of people simultaneously for social interaction," acknowledging the scalable and social nature of the virtual world while still approaching it from a single world perspective and incorporating augmented realities as significant digital interactions [5].

Millions of dollars are being spent by a number of major computer companies, including Microsoft, Nvidia Corporation, and Facebook (now called Meta), to create a virtual world that aligns with the concept of the metaverse [6]. Similar to this, fast-food chains like Wendy's, Chipotle, Panera, and McDonald's, professional teams in sports like the Atlanta Braves, retail brands like Nike, Puma, Gap, Clarks, Tommy

Hilfiger, and Gucci, and entertainment brands like Disney have started looking into ways to interact with customers in the "metaverse" [7].

The subject matter of what the metaverse is and how big of a market it is begs to be answered in light of the metaverse's growing popularity and rising attention from around the world [8]. It appears that when asked to define the metaverse, professionals and business leaders have various responses. Some thinkers contend that the metaverse is already here, while others think it is continuing to evolve in its early phases [9]. Furthermore, the metaverse is described in the existing academic literature from both limited (e.g., single virtual worlds) and broad (e.g., a hyperconnected and interoperable shared digital realm merging physical and virtual realities) viewpoints. In conclusion, there is a great deal of uncertainty and a general lack of agreement regarding the definition and extent of the metaverse. Furthermore, Dwivedi et al. [10] apply a multi-perspective approach, gathering varying perspectives on the metaverse from over 40 researchers, while acknowledging the nascent nature of metaverse-related scholarly work [11, 12].

1.1 Definition and Characteristics

The metaverse is an expansive, networked virtual world that includes a multitude of augmented reality places, virtual environments, and immersive experiences. In essence, it's a large, communal virtual environment where users can communicate in real time with digital things and one another. Imagine it as the coming together of the internet, augmented reality, and virtual reality to create a seamless network where users may interact, work, play games, shop, and produce content, among other things [13].

Fundamentally, the metaverse is based on the concept of shared, enduring places that transcend specific platforms or applications. Users are able to move between multiple virtual environments with ease, bringing their identities, belongings, and experiences with them. In this connected digital world, active participation and co-creation are equally as important as information consumption [14].

Businesses and developers are looking into how the metaverse might be used for social interaction, education, entertainment, and business. It signifies a change in the direction of increasingly connected and immersive online experiences, which make it harder to distinguish between the real and virtual worlds and open up new possibilities for creativity, enjoyment, and cooperation. The metaverse is always changing and has the potential to change how we view and interact with the internet in the future [15].

The metaverse is characterised by a number of distinctive features that work together to create its own identity in the digital space. Integrating augmented reality (AR) and virtual reality (VR) technology to create immersive environments that users can navigate in real-time is fundamental to its nature [16]. The interconnectedness of this landscape facilitates smooth transitions between different virtual places, creating a persistent experience where users are able to carry their digital identity

and assets across several platforms [17]. The function of user-generated content is crucial since it promotes a cooperative atmosphere in which users actively participate in the development of the metaverse by creating structures, creating virtual objects, and producing a variety of content.

The creation of a digital economy, where virtual items have real-world value and are authenticated through transactions using block chain technology, is an intrinsic aspect. Avatars allow users to communicate with each other and express themselves, which fosters a sense of community among users. Social engagement is essential [18]. The metaverse is a multipurpose area for labour, learning, pleasure, and business that goes beyond discrete uses. The goal of immersion is to create experiences that are realistic and rich, by obfuscating the distinctions between the real and the digital realms. The metaverse presents a new model for online communication and cooperation because of its dynamic and ever-changing digital environment, which is defined by a persistent digital identity, ongoing evolution, and flexibility [19].

2 Historical Evolution

The notion of the metaverse, first introduced in Neal Stephenson's 1992 book "Snow Crash," has seen an intriguing historical development influenced by the collision of technological advancement and visionary literature [20]. For years, the concept was limited to science fiction, but in 2003, the advent of Second Life and other similar platforms signalled a turning point in the early twenty-first century. Users could build, interact, and trade in a virtual environment called Second Life. This gave rise to the metaverse's slow evolution and provided a look into the promise of immersive online experiences [21].

With the rise of social media sites, online gaming platforms, and augmented reality experiences, the landscape continued to grow. These various online environments each added something special to the developing idea of the metaverse, which helped it to flourish. But the real turning point was brought about by more recent technology developments that combined to quicken the metaverse's development [22].

Blockchain technology transformed the digital world by giving virtual assets the qualities of scarcity and ownership, most notably through the use of non-fungible tokens (NFTs). This metamorphosis transformed digital goods into valuable commodities and changed users' perceptions of and interactions with digital material. NFTs emerged as a key component in the growth of the metaverse, stimulating innovation and creating new economic structures in virtual worlds [23].

With its 2021 rebranding and grandiose promises to construct the metaverse, Meta—formerly Facebook—made headlines. Beyond conventional social media, Meta envisions a spatial computing platform that combines virtual and augmented reality in a seamless manner. The business aims to create a metaverse where people may interact, work, study, and socialise in ways that go beyond what is possible in the real world [24].

The growing popularity of the metaverse has shifted the focus of important conversations to issues like digital identity, privacy, and ethics. The metaverse's historical trajectory displays the ramifications of an increasingly interconnected digital existence for society and philosophy, in addition to technological advancements [25]. As a transformative force in this ever-changing world, the metaverse offers never-before-seen chances for creativity and poses important concerns about the nature of existence and human connection in the digital age. The way we view and interact with virtual and physical worlds is changing as a result of the metaverse's ongoing evolution inside this intricate web of society dynamics and technology [26].

2.1 Milestones in Metaverse Development

The metaverse"s journey, an evolving concept that encompasses virtual shared spaces, has been marked by transformative milestones that reflect technological advancements and shifting societal dynamics. Virtual worlds, as exemplified by Maze War and Habitat in the 1970s and 1980s, laid the groundwork for the metaverse by introducing the concept of immersive digital spaces. However, the release of Linden Lab's Second Life in gave the metaverse a tangible form. 2003 [27]. Second Life offered users a three-dimensional virtual environment that demonstrated the potential for social interactions, creativity, and virtual commerce within a digital realm. Simultaneously, the rise of Massive Multiplayer Online Games (MMOs) like World of Warcraft and EVE Online in the 2000s demonstrated the allure of large, persistent online communities [28].

The integration of social media into virtual spaces occurred in the 2010s, as platforms such as Facebook and Twitter investigated the possibilities of virtual and augmented reality. Augmented reality applications, such as Pokémon Go in 2016, foreshadowed a convergence of the virtual and physical worlds. In the same decade, blockchain technology and the introduction of non-fungible tokens (NFTs) played pivotal roles in shaping the metaverse's economic landscape. Blockchain provided a decentralised infrastructure that ensured secure and transparent transactions, whereas NFTs pioneered the concept of unique, verifiable digital assets, revolutionising digital ownership within virtual spaces [29].

As the 2020s approached, major technology firms like Meta (formerly Facebook), Google, and Microsoft began making significant investments in metaverse development. These businesses are collaborating to create interconnected virtual spaces that seamlessly integrate social interaction, gaming, and commerce. Spatial computing, a key development in the 2020s involving technologies such as virtual reality (VR) and augmented reality (AR), improved the immersive and interactive aspects of the metaverse even further. VR headsets and AR glasses bridged the gap between the physical and digital worlds.

From early virtual worlds and MMOs to the incorporation of social media, blockchain, and spatial computing, the metaverse's evolution has been a fluid one. These landmarks collectively represent a paradigm shift in how we perceive and

interact with digital environments [30]. The metaverse is poised for further transformation as technology advances, promising new dimensions for socialisation, work, and interaction in the ever-expanding digital realm.

2.2 *Influential Technologies and Innovations*

The rate at which users adopted the underlying technology underwent a revolution some time ago when they started establishing connections with one another through a wired communication system called the Internet. With the advent of mobile technology, consumers could now converse more conveniently at any time and from any location. Complementing wireless technology are smart devices like smart phones, computers, and PDAs, which are now creating the possibility of a truly ubiquitous society.

As predicted by Weiser and Brown [31], technology will eventually become so ingrained in society that it would be considered an integral part of day-to-day existence.

The pervasive devices and the services they provide will fundamentally alter both the way people live and the structure of society as a whole. Smart phones are one of these devices that are currently bringing a variety of services into the Metaverse. The term "metaverse," which combines the words "meta" (beyond) and "universe," refers to a three-dimensional virtual environment that mimics the real world. It is an amalgam of the internet, augmented reality, and virtual worlds. The Metaverse is comprised of four primary dimensions: augmented reality, life logging, mirror world, and virtual world. These dimensions are determined based on two criteria: external versus intimate and augmentation versus simulation [32].

Possibly the most well-known and well-publicized product produced by Apple Inc. is the iPhone. 2.5 billion applications were downloaded in 2009, and 99.4% of those downloads came from the iPhone's app store, according to a Gartner report. Considering that these various applications are primarily responsible for enabling Metaverse services, the iPhone appears to be the most promising option when it comes to the Metaverse universe.

Many of these applications were once PC web services. But compared to PCs, smartphones are genuinely personal and belong to a single person, so they enhance these applications by being location-based (GPS) and individual-based. For this reason, the terms Twitter, Google, iPhone, and Secondlife (T.G.I.S.) were created as a way to express this new love of technology. T.G.I.S. is similar to the idea of the Metaverse.

Even though smart phones cause an abrupt increase of Metaverse services along the service adoption curve, it would be fascinating to find out how to assess this change so that conclusions can be drawn.

One of the most talked-about subjects in the field of information systems for a long time is the adoption of IT services. Modern multipurpose appliances, however, do not fully fit into the paradigm of traditional IT adoption research. The spread of

IT products has been found to be influenced by a number of other significant factors, and the outdated models have come under fire for failing to take into account the sophisticated and networked technologies of today [33].

The challenges of applying conventional models to forecast the uptake of such services are illustrated by the development of peer-to-peer Internet-based services and their avalanche-like spread. Peer influence effects are anticipated because the diffusion of multipurpose devices is highly sensitive to and closely related to users' communities in the Metaverse. Adoption will therefore show up as an unexplainable interrupted time series of data. Rogers argues that the rapid growth stage of an S-shaped diffusion curve occurs when businesses that have adopted an invention come into contact with non-adopting businesses. This is because of the adopting businesses' demonstrably superior performance, which encourages non-adopters to follow suit.

The Bass model is another well-liked innovation diffusion model in the marketing domain. According to this model, there are two types of people who adopt innovations. Only word-of-mouth (internal influence) and mass media (external influence) can have an impact on one group of people. Bass referred to the first group as "Innovators," and the second group as "Imitators" [34].

While this is only one of the goals of diffusion models, innovation diffusion models have historically been applied in the context of sales forecasting. These models have been utilised by numerous researchers for descriptive inferences in addition to forecasting. For instance, Kobrin used the Bass model to demonstrate that the nationalisation of oil production is a social interaction phenomenon, and [35] used it to explain why consumer durable goods product life cycles (PLCs) are getting shorter due to rapid technological development. This model was utilised by [36] to illustrate the various diffusion patterns based on national cultures. As our goal is to quantify the Metaverse service adoption pattern influenced by innovation and imitation effects, we also selected the Bass model for this investigation.

3 Foundational Technologies

The immersive and networked nature of the metaverse, a multifaceted digital universe, is shaped by a number of underlying technologies. As essential cornerstones, virtual reality (VR) and augmented reality (AR) offer users unique, yet complimentary, experiences. Users are entirely submerged in computer-generated content through virtual reality (VR). environments, usually accessed through specialised headsets, promoting a more enhanced sense of presence and interaction. Contrarily, augmented reality (AR) superimposes digital content on the actual world, fusing the virtual and physical domains together and improving users' awareness of their environment [37].

Blockchain technology is essential to the metaverse because it creates an open, transparent, decentralised environment that fosters virtual economies. Blockchain ensures the authenticity and ownership of digital assets in the metaverse by enabling safe and verifiable transactions. One important aspect of blockchain technology is

the representation of distinct and indivisible digital assets by non-fungible tokens (NFTs). Because of this breakthrough, the virtual goods market has completely changed, making it possible to create, own, and exchange digital goods with actual, monetary value. NFTs have influenced everything from virtual real estate to in-game assets, and they have emerged as a fundamental component of digital ownership.

Enhancing the metaverse experience is another fundamental technology: spatial computing. By combining aspects of virtual reality and augmented reality, this technology makes it easier to comprehend and engage with the spatial aspects of a digital world. Through the use of tools like AR glasses and VR headsets, users can navigate and manipulate digital space with a physicality that makes it difficult to distinguish between the real and virtual worlds. These devices are a contribution to spatial computing.

As these technologies come together, the metaverse is revealed as a dynamic, networked digital environment where users can actively participate in the construction and development of the virtual world in addition to consuming content. Together, these core technologies create the framework that enables the metaverse to develop into a huge, immersive, and cooperative digital frontier that is reshaping how people interact, socialise, and do business in the rapidly changing digital landscape.

3.1 Virtual Reality (VR)

One of the main components of the metaverse is virtual reality (VR), which has developed into an immersive and interactive digital environment. Through customised headsets, users can enter and navigate computer-generated environments in the metaverse, where virtual reality (VR) surpasses traditional digital experiences and offers a significant departure from conventional interfaces. Users who experience this integration feel physically immersed in the virtual world, creating a link between the real and the virtual world. It goes beyond simple visual and auditory stimulation [38].

There are countless opportunities for social interactions when VR is used in the metaverse. Virtual communities develop into vibrant settings where users can interact with people from all over the world and communicate in real time [39]. The metaverse uses virtual reality (VR) to foster a sense of community that cuts across geographic boundaries, whether people are taking part in shared recreational activities, concerts, or virtual events. VR's transformative quality adds to the metaverse's reputation as a social hub where the virtual worlds' limitless potential replaces the physical world's boundaries.

Beyond socialisation, virtual reality (VR) has been integrated into the metaverse to facilitate collaboration in workspaces, allowing teams to communicate and work together in virtual settings. Beyond the confines of conventional video conferencing, businesses can hold virtual meetings, presentations, and cooperative projects. Even though the participants are geographically scattered, this immersive collaboration not only increases productivity but also cultivates a sense of presence that resembles physical co-location.

Furthermore, the metaverse takes advantage of virtual reality's potential to completely transform entertainment experiences. It is possible for users to take part in interactive and captivating activities, such as immersive storytelling, world exploration, and games that go beyond the conventions of traditional gaming. With tools and environments to create, share, and experience content in never-before-seen ways, the metaverse turns into a creative playground for users [40]. VR in education offers immersive learning experiences and useful training simulations because of its capacity to replicate real-world scenarios.

The incorporation of virtual reality within the metaverse fosters innovative modes of expression and innovation. Users can sculpt, design, and share their works of art with others in virtual environments that serve as canvases. People can add to the collective fabric of the digital universe in the metaverse, an ever-evolving, user-generated environment. The metaverse's potential as a vibrant and inclusive platform is demonstrated by the democratisation of creativity and expression [41].

VR in the metaverse presents novel ideas such as virtual real estate from an economic perspective. A digital real estate market is emerging as a result of users being able to purchase, sell, and develop virtual properties within these immersive environments. The digital economy is dynamic because companies can set up virtual storefronts and users can participate in virtual commerce. The distinction between the digital and physical economies is muddled in the metaverse as virtual products, services, and experiences acquire real value [42].

With VR technology developing further, there is more evolution of the metaverse ahead. A complex digital ecosystem is produced when VR is combined with other key metaverse technologies like blockchain and augmented reality (AR). By superimposing digital data over the real environment, augmented reality (AR) enhances virtual reality (VR) by improving the user's interaction and perception of their physical surroundings. Blockchain technology creates decentralised infrastructures that protect digital assets and ownership, guaranteeing the security and transparency of transactions within the metaverse.

The incorporation of Virtual Reality into the metaverse signifies a fundamental change in the way humans view and engage with digital spaces. Thanks to its immersive qualities, virtual reality (VR) can be used for socialisation, education, creativity, and commerce. This helps to establish the metaverse as a dynamic, connected digital frontier [43]. With the ever-expanding digital landscape, people's ways of engaging, creating, and conducting activities are about to be redefined by the metaverse, enhanced by the immersive power of virtual reality (VR).

3.2 Augmented Reality (AR)

With its seamless integration of digital and physical elements, augmented reality (AR) is a transformative and complementary technology that improves user experience in the metaverse. AR modifies the real world by superimposing digital

data on it, enhancing the user's perception of their surroundings within the metaverse, in contrast to Virtual Reality (VR), which submerges users completely in computer-generated environments [44].

Augmented Reality (AR) adds a layer of interactivity to the real world in the metaverse, allowing users to interact in real time with digital content. This integration touches on many facets of daily life, such as communication and teamwork as well as exploration and navigation. Augmented Reality (AR) technologies offer users a higher level of awareness and interaction by giving them contextual information about their surroundings [45].

Spatial computing, in which virtual components are smoothly incorporated into the real world, is one prominent use of augmented reality in the metaverse. When using AR-capable devices, like smart glasses or mobile phones, users can see information or digital objects superimposed on the actual environment [46]. Users are able to manipulate virtual objects within their physical surroundings, making metaverse interaction more intuitive and immersive thanks to this spatial awareness.

Furthermore, AR technologies improve communication within the metaverse. In order to enhance the social aspect of the metaverse and create a sense of co-presence, users can participate in augmented reality conferences, in which holographic or digital avatars of real people are integrated into scenarios. By giving users a more engaging and dynamic experience, this method of communication goes beyond standard video conferencing [47].

AR in the metaverse not only improves everyday interactions but also plays a critical role in sectors like retail and commerce. Before making a purchase, users can use AR to see virtual products in real-world settings. AR technologies, for instance, make virtual try-on experiences for accessories or apparel more accurate and immersive by simulating how the items would appear in the user's physical environment.

Moreover, augmented reality enhances the metaverse's educational environment. Users of augmented reality learning environments can interact with three-dimensional models, simulations, and instructional materials superimposed on their environment. By blending the boundaries between traditional and digital learning, this use of AR creates a more dynamic and engaging learning environment.

A synergistic effect that improves the user experience overall is produced by the metaverse's integration of virtual and augmented reality. AR enhances VR by acting as a link between the virtual and real worlds, giving users more flexible and contextually aware metaverse interaction. These technologies work together to create new opportunities for creativity, collaboration, and information consumption in the ever-expanding metaverse, as well as to change how people view and interact with digital spaces [46]. The smooth assimilation of augmented reality (AR) into the metaverse is set to revolutionise user interaction and participation in this ever-evolving digital landscape as long as technological breakthroughs persist.

3.3 Block Chain and Its Role in the Metaverse

In the metaverse, block chain technology is a key component that both underpins and transforms the way digital assets, ownership, and transactions are handled in this vast virtual space.

Within the metaverse, blockchain functions as a distributed, decentralised ledger that logs transactions via a computer network [48]. Because it is decentralised, there is no longer a need for a central authority, giving the digital transactions that take place within the metaverse transparency, security, and immutability.

Block chain's establishment of transparent and safe virtual economies is one of its main functions in the metaverse. Blockchain technology allows users to conduct transactions with assurance because the ledger can be independently verified and tampered with. With ownership records permanently saved on the blockchain, virtual assets—from in-game items to digital real estate—can be safely purchased, sold, and traded [49].

The metaverse has seen a rise in the use of non-fungible tokens (NFTs), a particular use of blockchain technology. Digital assets like virtual art, collectibles, and in-game items are represented by NFTs, which are unique and indivisible. A traceable record of ownership and legitimacy is offered by each NFT, which is kept on the blockchain. By giving users actual ownership over their virtual assets and the freedom to easily transfer or sell them across multiple platforms, this has completely changed the idea of digital ownership [50].

Non-fungible tokens (NFTs), a specific application of blockchain technology, have become more popular in the metaverse. Unique and indivisible NFTs are used to represent digital assets such as virtual art, collectibles, and in-game items. Each NFT is stored on the blockchain and provides a traceable record of ownership and legitimacy. The idea of digital ownership has been completely transformed by this, as users now have actual ownership over their virtual assets and can freely transfer or sell them across multiple platforms.

Block chain's metaverse capabilities are further enhanced by smart contracts, which are self-executing contracts with the terms of the agreement directly written into code. Advanced digital transactions and interactions are made easier by smart contracts, which automate and enforce the application of pre-established rules. Smart contracts have the ability to regulate virtual property transactions within the metaverse, guaranteeing a secure and untrustworthy process.

Beyond just its economic effects, blockchain also helps to safeguard intellectual property and prevent fraud in the metaverse. The ability to easily trace the provenance of digital assets is made possible by blockchain's transparency, which lowers the possibility of fraudulent activity and creates a safe environment for both users and creators [10].

Blockchain technology is playing a more and more important role as the metaverse develops. A sense of trust and authenticity is fostered within the metaverse by the decentralised, transparent, and secure nature of blockchain, which also supports the operation of virtual economies. As blockchain technology advances, the metaverse

will gain access to increasingly complex and decentralised applications, which will further influence this evolving digital frontier's future [19].

4 Metaverse Implications on Society

The advancements in science and technology (S&T) shape our abilities to think, do, and imagine. Due to its potential to have a major impact on society in the near future, one of the most recent examples of techno-scientific progress has created a great deal of excitement about the future possibilities conveyed by the Metaverse. A strong socio-technological vision for the Metaverse has been put forth, stating that a variety of sensing devices, ubiquitous computing systems, and wireless networks that are able to perceive, think, feel, and react to both human users and their virtual representations—avatars with multiple personalities and identities—will be interwoven with the immersive, persistent, transcendent, concurrent, shared cyberspace. Though the Metaverse revolves around avatars, it is still a fictional representation rather than a socio-technical imaginary in terms of its possible delivery and fulfillment. In addition to being future-oriented and predicated in some ways, socio-technical imaginaries may also be seen as having the ability to shape terrains of choice and action in the future. As a result of the convergence of data-driven technologies and immersive technologies, the Metaverse proposes a hypothetical network of 3D virtual spaces in which people can socialize, interact, engage, connect, learn, work, shop, play, and much more [51]. By combining data-driven technologies and immersive technologies, the Metaverse is envisioned as an aways-on virtual network with a multitude of possibilities for socializing, interacting, connecting, learning, working, shopping, playing, and so many other things. Metaverses will represent lifestyles in plausible virtual cities that are very dissimilar from anything that users of humans have encountered thus far. This leads to a fresh perspective on urbanism in that sense, as data-driven and technologically powered urban environments [52].

Research and development of the Metaverse has arisen as a prominent trend in data-driven smart urbanism designs, since large-scale data-driven Artificial Intelligence (AI) systems allow the building of virtual or augmented cities. A set of socio-technical imaginaries, or performative visions of perfect future urban environments supported and enabled by infrastructures, activities, services, and widely accepted definitions of social life and social order, can be used to conceptualize the idea of the data-driven smart city. The Metaverse is an amalgam of fictitious portrayals of future virtual worlds that provide warnings and optimism simultaneously, along with unsettling predictions of what is to come. Social scientific literature contains fictionalized depictions of technologically enhanced urban worlds, virtualized in this case, that reflect the deconstructive critique of the techno-utopianism of urban imaginaries in technologically advanced societies, which frequently serve as symbols of socially alienating corporate and oppressive governmental power. Moreover, a lot of the time, the idea of the Metaverse is based on unrealistic scenarios that have no historical significance. As a result, the development of the Metaverse is mostly

restricted to theoretical or speculative realms. This can be seen in the efforts made by the Metaverse to restructure and alter how people engage with cities and other spatial forms [53]. Nevertheless, it is unlikely that cities and urban life would disappear from people's perceptions in the future, and it is unclear whether the Metaverse will manifest as a virtualized representation of data-driven smart cities. In fact, it is found that the socio-technical imaginaries of data-driven smart cities are being built, rebuilt, altered, and contested concurrently, with each of these discursive practices and processes influencing the manner in which urban action occurs—as well as the fictionalized future urban environments that are imagined [54]. Creating "wholly new, digitally enabled settings can too readily lead to restrictions in how the social milieu is defined within them and exclude or render invisible various social groups, cultures, behaviors of inhabitation, and places," according to the technologically dystopian Metaverse vision [55].

The misrepresentation of the "reality of a city" and the unique characteristics of certain places, such as the past, present, and future of urban communities, are among the social exclusion problems associated with data-driven smart cities. According to Kitchin, such systems should be seen as complex, open, multi-level, relational, fluid, and full of politics, culture, competing interests, and wicked problems that often manifest in unpredictable ways. Rather, this complexity is reduced in the Metaverse to AI-based models and limited, controllable digital platforms, from which individuals and their virtual places are guided and controlled.

The repercussions of the future worlds this view imagines are not taken into consideration, nor is it blind to the personal, social, and political complexity that defines the metropolis. This perspective implies that, similar to data-driven smart urbanism, living arrangements within the administrative borders of city systems are restricted, leading to a disregard for the experience of daily life. To regulate urban lifestyles, "citizens become functional datasets to be managed and manipulated" according to data-driven smart urbanism. Likewise, Aurigi notes that most of the discussion around the Metaverse, which, in reality, is a combination of multiple control-freak urban utopias, is similar to the "anti-urban, cyberspace-hailing hype of the 1990s."

4.1 Communication

A new era marked by unparalleled levels of immersion and interactivity is being ushered in by the emergence of the metaverse, which signals a seismic upheaval in the communication landscape. In this virtual space, people interact by taking on the form of avatars, breaking down barriers to conventional communication. By focusing on spatial communication, the metaverse presents a fresh idea of virtual presence, enabling a more realistic and immersive connection. Conversations are lively and lifelike because avatars occupy shared digital environments and because spatial audio and visuals heighten the sense of presence [56].

Virtual workplaces change team dynamics, giving rise to a new degree of collaboration within the metaverse. As people from different places work together smoothly in a same digital space, geographical boundaries become less relevant and promote more productive teamwork. The metaverse transforms into a testing ground for new ideas, dismantling obstacles that impeded cooperation in the real world [57].

People now mingle and communicate in virtual places, reimagining traditional social relationships. Individuals participate in group activities, attend virtual events, and explore digital surroundings in addition to standard texting and video conversations. This creates a social experience that is more profound and richer by fostering a sense of connection that transcends physical distance [58].

Custom avatars and virtual surroundings in the metaverse promote individuality and self-expression. Individuals have the ability to customize their virtual identities, promoting an artistic outlet that transcends the boundaries of the real world [59]. People may now express themselves in ways that were previously unthinkable because to this injection of customization, which opens up new avenues for connection.

But there are other issues with the metaverse as well that need to be carefully thought out. With communication moving into this vast digital space, security and privacy issues are major considerations. Protecting private data, stopping online harassment, and making sure virtual assets are secure become crucial factors in this changing environment [60].

Conclusively, the metaverse offers a revolutionary approach to communication by providing immersive, spatial, and customized experiences. Navigating the undiscovered frontiers of this evolving digital frontier will require tackling the related obstacles, even though it presents intriguing opportunities [61].

4.2 Entertainment

In the entertainment industry, the metaverse is a disruptive force that is changing things beyond traditional limits. A new age of profoundly experienced, rather than just consumed, entertainment has arrived thanks to this vast digital universe that is characterized by its immersive and interactive qualities. At the forefront of this revolution are technologies like virtual reality (VR) and augmented reality (AR), which immerse users in vibrant, three-dimensional worlds where they can interact with material. This evolution has taken many different shapes. One such manifestation is the emergence of virtual concerts, which allow fans all over the world to see live performances from the comfort of their homes. As players become fully immersed in finely crafted virtual worlds, gaming experiences have also reached previously unheard-of heights [62].

In addition to being a platform for consumption, the metaverse is a dynamic hub for innovation and content production. Innovative material that transcends the limitations of traditional media can be produced and presented by creators. Immersion theatre, collaborative projects, and virtual art galleries are all thriving in this digital space

and provide a window into the seemingly endless entertainment options available in the metaverse. In addition, the metaverse changes how people engage with each other in the entertainment industry by enabling users to meet people who share their interests in common digital places. In addition to interacting at live events, attendees can form virtual communities based on common interests and mix and mingle at virtual premieres [63].

With its ongoing development, the metaverse has the potential to provide unparalleled levels of innovation and cooperation while also democratizing access to entertainment. The lines separating the real and virtual worlds are blurring, opening up a whole new realm of entertainment options. This is more than simply a technical change; it's also a cultural and experiential revolution [64].

4.3 Education

A wide range of educational settings, such as science, medicine, nursing, and healthcare education; military training; manufacturing training; and language learning, could benefit from the application of the metaverse. Because of these characteristics, it is anticipated that the metaverse in education will be different from traditional VR or AR-based education (Choi and Kim 2017).

Several prior studies have reported on the usefulness of using virtual reality (VR) to place learners in actual environments throughout an English as a Foreign Language (EFL) language learning course. fortunately the purpose of language learning is to give EFL students the ability to live another life, one in which they utilize English for employment, education, social interactions, and leisure, just like native English speakers would. This is seen from the metaverse perspective, where language learning is seen as more than just a course or an exercise. VR and the metaverse are two very different learning experiences [65].

The metaverse has a wide range of possible uses in education

(1) To place learners into situations where they can experience and learn things that they would not otherwise have the chance to in the actual world.
(2) To make it possible learners to understand or absorb knowledge that calls for sustained practice and commitment.
(3) Encourage learners to try making or researching something that they can't realistically afford to do in the real world due to finances or a lack of appropriate tools.
(4) Providing students, the freedom to consider and try many things when it comes to their life or professions.
(5) To allow students to see, feel, or perceive things from many angles or roles.
(6) In order to provide students, the opportunity to practice interacting and perhaps working together with persons they might not have the chance to deal with in the real world.

(7) To engage students in challenging, authentic projects that will allow them to develop their potential for higher order thinking.

4.4 Business

With an abundance of potential and difficulties for businesses across industries, the metaverse has emerged as a disruptive force in the corporate world. This virtual world of immersive and connected experiences has an impact on how businesses function, interact with clients, and develop. A noteworthy feature is the possibility of virtual commerce in the metaverse, where companies can create a digital identity, market virtual products, and exchange digital currency [66]. This makes way for fresh markets and revenue sources, as well as new opportunities for e-commerce and digital business models.

The metaverse has redefined company operations through collaboration and communication. Teams who are physically separated can work together in shared digital spaces through virtual meetings and collaborative workspaces, which promote productivity and innovation. Beyond geographical boundaries and enabling worldwide participation, the metaverse provides a unique venue for conferences, product launches, and networking events [37].

Furthermore, the creation of novel technologies is being facilitated by the metaverse, which serves as a platform for invention. Educational, healthcare, and training sectors are being revolutionized by applications of augmented and virtual reality, integration of artificial intelligence, and immersive simulations. These days, companies are using these tools to improve customer experiences, replicate real-world situations, and improve staff training.

Businesses in the metaverse face issues pertaining to privacy, security, and ethical considerations, even with the potential benefits. Virtual property rights, secure transactions, and the protection of sensitive data become critical issues [67]. Moreover, enterprises looking to profit from this new digital frontier face difficulties in navigating the metaverse's changing regulatory environment.

In summary, the metaverse is changing the corporate environment by providing new channels for trade, cooperation, and creativity. In this age of digital transformation, companies who proactively embrace and adapt to the metaverse will have a competitive advantage over those that ignore its implications. Businesses will need to traverse a challenging terrain as the metaverse develops in order to fully realize its promise and handle the difficulties that come with it [68].

5 Comprehensive Exploration of the Metaverse

A remarkable combination of immersive technologies and networked virtual worlds, the metaverse offers a thorough examination of a digital frontier that is transforming the fundamental structure of our online lives. It is essentially a group virtual shared environment in which users navigate three-dimensional spaces with the aid of avatars, combining elements of augmented reality, virtual reality, and spatial computing. Users can interact and engage in a level of interaction and engagement never before possible thanks to this convergence, this makes it difficult to distinguish between the virtual and actual worlds. Alongside its entertainment value, the metaverse contributes to a burgeoning digital economy powered by digital assets, decentralized digital currencies, and non-fungible tokens (NFTs).

Companies are entering this market online and transforming traditional trade into a dynamic, block chain-powered ecosystem.

The metaverse is characterized by its technological integration, where intelligent, immersive digital environments are created by the convergence of cutting-edge breakthroughs like block chain, artificial intelligence, and augmented and virtual reality. Virtual simulations and augmented reality apps are transforming traditional procedures in the education and healthcare sectors, thus this integration affects more than just entertainment. Users are able to create customized digital personas and participate in real-life social interactions, giving social dynamics in the metaverse a new dimension. Experiences in the metaverse can be customized to suit personal tastes, whether one is exploring educational environments, taking part in collaborative workspaces, or attending virtual events.

Nevertheless, as the metaverse expands in its potential, it also presents new difficulties that require careful thought. Careful navigation is essential in virtual places due to privacy concerns, security risks, and the requirement for ethical governance. The metaverse promises a future where the actual and virtual worlds intermingle, reshaping our perception and interactions of the digital world as we navigate this ever-changing digital terrain. It also has the potential to revolutionize communication, business, and innovation.

5.1 Potential Impact on Interconnected World

The metaverse possesses the capacity to significantly influence our globalized world by revolutionizing the ways in which we cooperate, exchange information, and live together. This is due to its immersive and networked digital environment. Geographical barriers are broken down as the metaverse develops into a centre for international cooperation, providing shared digital places where people from all over the world can participate in interactive, real-time experiences. Beyond only facilitating communication, this revolutionary power transforms how we do business by creating a global digital marketplace that dissolves obstacles to commerce and finance. The metaverse

presents a new economic paradigm in which digital assets, decentralized currencies, and virtual trade all play essential roles in our globalized economy [16].

Within the metaverse, cultural exchange—a fundamental component of global interconnectedness—takes on a dynamic aspect. It is possible for diverse cultures to coexist peacefully and create a rich tapestry of common experiences that cuts across geographical boundaries. People from different origins could become more mutually appreciative, cooperative, and understanding of one another in this integrated cultural sphere. The metaverse also has a big influence on education, offering options for holistic and cooperative learning outside of conventional educational environments. Participating in shared virtual environments allows educators and students from all over the world, democratizing access to knowledge and skills [15].

Social connectedness is paramount in this networked metaverse, offering a means for people to create online groups, go to events, and exchange experiences with others worldwide. This interwoven social fabric makes people feel like they belong in a global setting and promotes an accepting and understanding society. But as we explore the metaverse's possibilities, it's critical to solve problems like security flaws, privacy issues, and moral dilemmas. Harnessing the metaverse's great potential and ensuring that its influence on our interconnected world is transformative, inclusive, and morally sound requires responsible development and governance. In the end, the metaverse presents unheard-of chances to transform the world and make it more linked, multicultural, and collaborative.

5.2 Opportunities and Challenges

Our digital experiences could be completely reshaped by the metaverse, an enormous and rapidly developing digital frontier that offers a diverse range of opportunities and difficulties. Virtual trade and digital economies represent one of the main areas of opportunity. Enterprises can utilize the metaverse to create a worldwide digital footprint, surpassing physical boundaries and participating in decentralized exchanges enabled by virtual currencies and assets. This updates established company models while also providing new sources of income [12].

Simultaneously, the metaverse transforms social relationships by offering personalized, immersive experiences that surpass physical boundaries. People may connect, communicate, and socialize in previously unthinkable ways thanks to virtual events, shared digital surroundings, and collaborative workspaces. These technologies also help to create a feeling of global community. This globalized social fabric transforms the dynamics of interpersonal connections by improving global communication and collaboration [38].

Technological innovation is a key element of the metaverse, incorporating modern technologies such as blockchain, augmented reality, virtual reality, and artificial intelligence. This convergence offers revolutionary breakthroughs in fields including

enterprise, healthcare, and education in addition to driving ground-breaking applications within the entertainment sector. The metaverse serves as an exploratory sandbox by pushing the boundaries of what is possible in the digital age [46].

But there are obstacles to overcome when traveling the metaverse. As consumers immerse themselves in this digital environment, privacy and security concerns become increasingly important. To guarantee a safe and reliable metaverse experience, protecting personal information and stopping illegal access become essential requirements. Furthermore, there's a chance that the metaverse will exacerbate online inequality. As a requirement for complete engagement in the metaverse, access to cutting-edge technology has the potential to exacerbate already-existing gaps by highlighting differences in digital literacy and resource accessibility [3].

Given the metaverse's embryonic state and rapid evolution, ethical and regulatory quandaries arise. It becomes imperative to establish responsible frameworks that steer the ethical development and utilization of the metaverse in order to tackle concerns pertaining to digital rights, virtual property, and user protection. To guarantee a metaverse that flourishes while upholding moral standards, it is imperative to strike a balance between innovation and regulation [33].

In addition, it is important to give serious thought to issues related to addiction and possible effects on mental health. A careful balance between engaging experiences and ethical use is necessary since There are issues with the metaverse's pervasive nature about the possible effects on users' wellbeing.

Finally, the metaverse emerges as a space full of chances for creativity, cooperation, and financial revolution. However, in order to guarantee a responsible and inclusive evolution, its route is paved with obstacles that call for careful answers. Utilizing the metaverse to its fullest potential as we navigate this ever-changing terrain calls for a comprehensive strategy that balances opportunity maximization with the challenges and moral dilemmas that come with this new digital frontier [49].

6 Conclusion

We are at the crossroads of significant opportunities and complex challenges that characterize this developing digital world in this final chapter of our investigation into the metaverse. The metaverse is a monument to human creativity and technology growth, offering immersive experiences, global connectivity, and economic transformation. The metaverse presents a compelling image of a digital future full of opportunities, from virtual commerce creating new commercial opportunities to the redefining of social relationships and the creative integration of cutting-edge technologies.

There are also challenging threads woven throughout this intriguing tapestry that call for cautious thought. Users who are fully engaged in this connected digital world are confronted with privacy and security issues, which calls for strong measures to protect personal information and uphold confidence in virtual environments. Concerns of inclusivity, access, and the fair sharing of the metaverse's advantages

are brought up by the possible escalation of digital inequality. A careful governance system that balances preserving user rights with promoting innovation is necessary, as demonstrated by ethical and regulatory quandaries.

This chapter's conclusion makes it abundantly evident that the metaverse is a cultural, sociological, and economic phenomenon that calls for a comprehensive viewpoint rather than merely being a technology phenomenon. Collaboration between politicians, ethicists, users, and technology pioneers is crucial in navigating the intricacies of the metaverse's emergence. In-depth debates, assessments, and insights that shed more light on the future will be provided in the upcoming chapters that will go deeper into these nuances. Our collective future digital story is being painted on the metaverse, and it is our job to make sure that diversity, accountability, and the advancement of the international community are all reflected in this narrative.

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From Avatars to Allies: Understanding Social Dynamics in the Metaverse

S. Mahalakshmi, H. Bharath, and Sandeep Kautish

Abstract "From Avatars to Allies: Understanding Social Dynamics in the Metaverse" explores the complex realm of social interaction in virtual spaces. Understanding the processes guiding these encounters is crucial as digital places grow more and more integrated into our social fabric. This chapter examines the various facets of social interaction in the metaverse, including the development of communities, the navigating of identities, and the forming of relationships. This investigation centers on the idea of avatars, which are digital personas that facilitate communication and expression between people in virtual spaces. Individuals navigate the metaverse with the use of avatars, participating in a variety of social interactions that span from lighthearted discussions to cooperative projects and even deep emotional bonds. The complexity of virtual social dynamics becomes clearer when one comprehends how avatars influence interactions and perceptions. Furthermore, explored in this chapter is the function that communication and empathy play in creating deep bonds in the metaverse. In order to establish real connections and cross-cultural barriers, people must be able to empathize and communicate well with one another when they engage with different avatars. The metaverse idea of allies is examined, emphasizing the value of cooperative partnerships in accomplishing common objectives and promoting societal change. In the metaverse, people can come together and bring about constructive change through activities like group problem-solving and virtual activism.

Keywords Metaverse · Social dynamics · Community · Virtual activism · Communication · Empathy · Digital spaces

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1 Introduction

The Metaverse's explosive rise to prominence in the quickly changing field of digital interaction holds the potential to completely transform the ways in which people interact, work together, and create in virtual spaces [1]. Knowing the complex social processes underlying interactions in the realm of the Metaverse becomes critical as we navigate this new frontier. Some of the biggest technology companies in the world are interested in the metaverse. Microsoft and Facebook, for example, are pouring billions of dollars in virtual reality hardware and software. Facebook has flingly rebranded itself as Meta [2].

The idea of the avatar, an animated version of the individual that acts as an interface for interaction in virtual places, is central to the Metaverse. Avatars are more than just images on a screen; they represent the goals, emotions, and connections of their users, reshaping the Metaverse's social interaction scene. However, under the surface of visual representation is a complex web of social cues, conventions, and dynamics that influence how people interact and navigate these virtual environments [3]. Considered "the holy grail of social interactions" by Meta CEO Mark Zuckerberg, for instance. Administrators see the metaverse as a setting where RMSIs may offer businesses and customers greater benefits than two-dimensional computer-mediated settings like Discord, Zoom, and Skype. This reasoning is supported by financial analysts, who estimate that the metaverse will produce several trillion dollars a year due to a significant commercial shift from the 2D internet [22].

Beyond the confines of conventional social media platforms, the Metaverse provides immersive experiences that stimulate a heightened sense of presence and participation. Users are immersed in intricately detailed virtual worlds where they may participate in activities, exchange experiences, and collaborate in real-time on content creation with others thanks to the utilization of spatial audio, realistic physics, and interactive components [22]. Whether engaging in cooperative projects, going to virtual events, or just hanging out with pals, the Metaverse provides a flexible setting for social interaction that goes beyond time and space barriers.

Technologies like virtual reality (VR), augmented reality (AR), and spatial computing have made the Metaverse immersive, which is one of its distinguishing characteristics. By blurring the boundaries between the real and virtual worlds and enabling deeper, more engaging experiences within the Metaverse, these immersive technologies foster a sense of presence and immersion. Users can connect with content and with others in previously unthinkable ways by exploring virtual landscapes and attending virtual concerts, among other things (Mottelson and Maes 2018).

The Metaverse extends the reach of traditional social media platforms by offering immersive experiences that promote increased involvement and presence. Spatial audio, realistic physics, and interactive elements are used to immerse users in highly detailed virtual environments where they may engage in activities, share experiences, and work together in real time on content production. The Metaverse offers an adaptable environment for social interaction that transcends time and location

limitations, whether participating in cooperative projects, attending virtual events, or simply hanging out with friends.

1.1 Crafting Digital Identities

- **Personalizing Your Avatar: The Art of Expressing Yourself**

People can project their preferred appearance onto the virtual world via avatars, which act as digital proxies for their users and act as a canvas for self-expression. With nearly endless customization options, users may create avatars that accurately represent their individual identities and goals, from choosing facial traits and body types to selecting clothing styles and accessories [4]. Users give their digital avatars agency and authenticity by carefully selecting every element of them, which helps them connect and develop relationships based on common beliefs and interests.

Avatar customization also takes into account more profound aspects of identity and representation than just aesthetic looks. Users blur the lines between the real and virtual worlds by giving their digital avatars personalities, gestures, and mannerisms through the adoption of these pronouns. By extending their offline identities into their digital avatars, users not only manage social interactions in the Metaverse but also mold their own identity and self-perception [5].

Aside from encouraging individual creativity, the practice of customizing avatars in the Metaverse adds to the diversity and depth of online communities. Through embracing a culture that emphasizes authenticity and self-expression, users create connections and a sense of belonging in virtual spaces, forming relationships with people who have similar interests and values. Avatars work as social media spark plugs, igniting interactions, partnerships, and friendships that go beyond the confines of the virtual world [5].

To sum up, customizing an avatar in the Metaverse offers you the chance to express yourself, interact with others, and create a digital identity in a virtual world—it's not simply a pretty exercise. Users enhance the vibrant and dynamic nature of virtual communities by skillfully customizing their avatars, so contributing to the richness of the collective human experience inside the Metaverse.

- **Creating an Identity in Virtual Environments**

Developing a digital identity in virtual settings is a complex process that includes building, expressing, and maintaining a digital identity in digital spaces. People can create identities that transcend the limitations of the real world in virtual environments like the Metaverse, giving them unmatched freedom of expression and self-representation (World economic forum, 2024).

Customizing one's avatar is a crucial part of establishing one's identity in virtual settings. Users can visually represent themselves in virtual places through the use of avatars, which act as their digital incarnations. People may personalize their avatars to represent their interests, goals, and personalities by adjusting their appearance, attire,

accessories, and gestures, among other customization choices [5]. Customizing one's avatar allows users to reflect their preferred image onto other members of the virtual community in addition to facilitating self-expression.

It also requires social contact and relationship building to establish an identity in virtual worlds. By use of communication capabilities like voice, text, and gesture chat, users can interact with one another, establish friendships, and create communities around common interests and ideals. Because they offer chances for social validation, self-expression, and self-discovery, these social interactions are vital in helping people form their identities in the virtual world (World Economic Forum, 2024).

In virtual environments, creating an identity is also a dynamic and continuous process that is influenced by personal encounters, relationships, and decisions. The exploration and self-expression options people find when navigating virtual places might result in the gradual development and improvement of their digital identities [5].

Due to its flexibility, identities can be modified by users to fit various virtual environments and social dynamics.

- **Social and Cultural Aspects of Avatar Creation**

Avatars, our virtual friends, are more than just images on a screen. Their work is an intriguing tapestry made of cultural and social influences. Avatar creation systems offer a range of design possibilities that reflect different cultural perspectives on beauty, gender roles, and social status. As an illustration, a recent study by [6] shows how our perception of even the most basic avatar qualities can be influenced by our cultural background. Still, avatars are more than just inert reflections. They enable us to create an online identity that fits societal norms or even allows us to explore identities that are forbidden in the real world. When one considers representation, the importance of this self-presentation technique increases (Ratan et al. 2019). To prevent offending users, the variety of avatar choices ought to reflect the makeup of the user community. Ultimately, a more accepting and inclusive online community cultivates a feeling of community.

Avatar etiquette is evolving along with internet cultures. Different social networking sites have different expectations. For example, Bitmoji, a site that features cartoon avatars, may have a more laid-back vibe than Second Life, a site that emphasizes hyper-realistic depictions. Fascinatingly, avatars' influence extends outside of virtual environments. We might potentially shape our interactions in real life by letting our online identities affect how we view ourselves and how others see us. Avatars have been shown in studies to increase self-confidence, particularly in people who might feel excluded from their live communities (Ratan et al. 2019).

2 Navigating Virtual Spaces

- **Spatial Awareness and Presence**

The metaverse's ability to completely transform social interaction is what makes it so alluring. However, presence and spatial awareness are two essential components needed for this magic to work. Think of your avatars as extensions of yourself, living smoothly in a virtual environment instead of awkward figures limited to a screen. The foundation is laid by spatial awareness, which enables your avatar to sense its environment [7]. It can move fluidly across the metaverse, recognizing its layout and the locations of other avatars. This understanding translates into a sophisticated social vocabulary. Similar to physical proximity in the real world, proximity in the metaverse denotes private communication, whereas distance implies a public address. Leaning in indicates curiosity, a solid virtual handshake transforms into a greeting, and pointing lets you tell others about the wonders of the metaverse [7].

However, feeling fully present with others is the essence of spatial awareness, not merely knowing where you are. Imagine exchanging objects with ease while working together on a virtual project. Imagine being at a concert and feeling the energy of both the virtual band and the audience rush over you. Being present enables us to experience being a part of the metaverse, not only seeing and hearing it. Even though the technology is still being developed, it has incredible promise. We can create deep social ties based on the presence and common experiences in the metaverse, in addition to forming connections there [8]. Virtual senses such as sound and smell may eventually be included in spatial awareness as it develops further. Envision the depth of interpersonal communication when you can perceive a virtual flower, smell its delightful aroma, and feel the gentle breeze blowing it in your direction. Geospatial awareness is the key to navigating the infinite social interaction opportunities found in the metaverse [7].

There are fascinating problems associated with this new technology. One of the most important challenges to conquer is accurately monitoring user movement and developing realistic virtual physics. However, there is no denying the possible benefits. The ability of the metaverse to transcend the confines of physical location can result in social relationships that are more complex, subtle, and ultimately human. We can change the metaverse into a dynamic social environment where interaction and shared experiences are the norm by embracing spatial awareness and presence [14].

- **The Metaverse's Social Standards & Etiquette**

Entering the social realm of the metaverse is akin to exploring an unfamiliar territory. Its social terrain may be interesting, but you need etiquette as your compass. How to guarantee a smooth sailing experience. It's important to have personal space. Avoid packing your avatar with too many people; their stance or a virtual "bubble" may suggest they are comfortable. Recall that nonverbal cues can convey meaning. To show appreciation and take an active role, use gestures like nods or waves. Show up! Prevent multitasking, pay attention to exchanges, and express sincere curiosity.

Accept variety because a wide range of avatars is what the metaverse needs to survive. No matter how someone seems online, treat them with dignity [9].

Words have an impact. Keep your words and acts civil and don't interfere with other people's enjoyment. Consider a virtual community to be the metaverse. Understand the laws as they are written and refrain from doing harm. Be careful while disclosing personal information, but feel free to express yourself. Know when to leave, finally [7].

Make a nice excuse if someone appears disinterested. Weave a positive social fabric in the metaverse by adhering to these straightforward rules. Encouraging polite interactions is the first step towards realizing the enormous potential for connection in this virtual environment. It is our joint duty to create a vibrant social environment in the metaverse, keeping in mind that it is a shared area [9].

- **Setting Up Individual Limits in a Digital World**

A good set of boundaries is necessary as protection when stepping into the digital world of the metaverse, which beckons with a universe of social connection. To guarantee that your real life flourishes alongside your virtual experiences, schedule specific metaverse sessions, just like you would with screen time. To help you avoid becoming lost in limitless encounters, set timers within the metaverse itself. Privacy protection is essential. You may choose on a lot of platforms that can interact with you and view your avatar [9]. Create your social network and keep out of undesired relationships by using these parameters. As well, create comfort zones. To establish a feeling of personal space, make use of tools like virtual "bubbles" or just express your preferences outright.

Avatars aren't the only thing in the metaverse; you may also engage with the material. It's okay to turn down the volume. Utilise the mute and block features to control your exposure to stressful or negative environments. Customizing your virtual feed is possible on several platforms. Select material that encourages constructive interactions and is in line with your interests. But keep in mind that your wellbeing transcends digital realms. It might be exciting to explore the metaverse but be mindful of your emotions. If negativity starts to seep in, put your mental health first and take a vacation from the cyber world. The real world is also important [10]. To achieve a healthy balance, schedule time for relationships and activities that take place outside of the metaverse. Establishing limits requires constant effort. These tactics should be customized to your needs and modified as you proceed.

3 Building Virtual Communities

- **The Significance of Common Interests and Hobbies**

The metaverse is a community ecosystem that is based on common interests rather than merely being a collection of pixels. Social bonds are formed by shared interests,

which go well beyond a casual greeting. Picture a metaverse gym where avatars high-five one other after a strenuous workout, or a virtual art gallery where conversations about brushstrokes and symbolism are vibrant. These common interests create a sense of community and acceptance that goes beyond the internet; they do more than just spark discourse [9].

However, the magic extends beyond interactions at the surface level. Book clubs debate the nuances of story and character, and online gardeners provide advice on taking care of their virtual plants. Using virtual blueprints that their avatars manipulate, architects work together to create amazing constructions. We may genuinely interact with people in meaningful ways through the metaverse, rather than just connecting with them based on common interests. These communities develop and become centers for ongoing education. In virtual observatories, astronomy societies come together to study the universe and share their astonishment at far-off galaxies. Cooking groups in the metaverse push the limits of their culinary imagination by experimenting with unique recipes in imaginative kitchens [10].

These online groups' inclusiveness is what makes them so delightful. People from all around the world can connect over their shared interests thanks to the metaverse, which removes geographical boundaries. Whether it's competing in an international dance competition or discussing the newest film release with other film enthusiasts, common interests provide a sense of connection that cuts across geographic boundaries. To put it simply, finding common ground in the metaverse facilitates more gratifying virtual experiences, richer social interactions, and cooperative projects. It's a place where friendships grow, shared passions ignite, and knowledge is shared within the colorful metaverse fabric [9].

- **Governance and Moderation in Communities**

The metaverse is full of opportunities for vibrant online communities, but like any society, these places require direction. The foundations of constructive social engagement in the metaverse are moderation and effective governance. Imagine unambiguous rules that prohibit harassment and encourage respect—a kind of virtual social contract. This code of conduct establishes guidelines and promotes a welcoming, safe environment for everybody. Conflicts will inevitably arise, therefore having a clear procedure in place for handling them is essential. To provide just and effective resolutions to disputes, moderators may take on the role of mediators. User-generated content is welcome in the metaverse, although the experience is curated in part via moderation. Moderators keep everyone in a safe and comfortable virtual environment by weeding out offensive material [11].

However, community empowerment is essential to ensure that governance is not a tyranny. They are able to report inappropriate behaviour and take part in conversations about preserving a welcoming social atmosphere. Lastly, virtual communities should change along with their government. Structures that are adaptable and can change with the needs are crucial. It is important to regularly evaluate and update rules to make sure they stay current and maintain their ability to build a sense of trust and community. Rich social connections and a satisfying virtual experience are facilitated

by efficient governance and moderation, which are fundamental components of a flourishing metaverse society [9].

- **Encouraging Diversity and Inclusivity in Virtual Environments**

A world without boundaries and a welcoming social environment are what the metaverse beckons with. This vision is centred on diversity and inclusivity. Picture a virtual society where languages flow naturally between them, cultures are honored, and avatars represent the diversity of humanity. Beyond being sentimental, this inclusivity helps everyone feel like they belong. Social links based on common experiences can be formed in the metaverse by people from different identities and cultures. Moreover, accessibility is crucial. There should be no closed-door policy in the metaverse. Participation is guaranteed for all users thanks to features that accommodate limitations, such as voice commands or alternate controllers. Further expanding the welcome mat are a range of virtual surroundings that cater to various interests. Nonetheless, inclusivity extends beyond accessibility [12].

A varied community needs open communication to survive. Imagine a global art display featuring a rainbow of artistic expressions, or a virtual town hall humming with ideas from all around the world. It is on these forums for free communication that understanding grows and boundaries across cultures dissolve. A fuller metaverse is ultimately one that is inclusive and diverse. We create a dynamic virtual environment that encourages meaningful relationships, collaboration, and a genuine feeling of community for everyone by accepting a range of experiences and viewpoints. It's a place to appreciate diversity and explore the endless opportunities presented by this fascinating new frontier [9].

4 Communication and Collaboration

- **Communication in Digital Environments: Both Verbal and Nonverbal**

The boundaries of our displays don't define the connections we make in the metaverse. A more complex social fabric is produced by the combination of verbal and nonverbal communication. Text chat is still essential since it enables meaningful discussions in virtual conference rooms and lets users leave messages for friends who aren't online. However, voice conversation introduces a whole other level. Avatars exploring virtual worlds together might have impromptu talks, with their voices contributing to a natural flow and emotional connection. This is extended further via spatial audio. Not only are conversations heard, but they are also experienced. Envision the contrast between a hushed conversation in a packed virtual room and a private conversation with the speaker's avatar centred in a quiet nook [13].

A significant part is also played by nonverbal communication. Our avatars become extensions of ourselves, communicating with us through their appearance and attire. Consider the difference between an avatar dressed professionally for a virtual business meeting and one equipped with hiking gear for a virtual jungle exploration.

Avatars can nevertheless convey intentions and feelings through body language, despite it not being as subtle as in real life. Shrugs, waves, and virtual handshakes can all communicate a lot. Not to be forgotten are emotes and emojis, which give text conversations a fun element of expression. Consider utilising a joyful emotion to celebrate reaching a goal in a virtual game or sending a thumbs-up emoji to show approval.

The metaverse provides an entirely new kind of communication experience by skillfully fusing verbal and nonverbal features. We can express ourselves more completely thanks to it, which strengthens our bonds and increases our sensation of presence in this fascinating new virtual environment [14].

- **Breaking Through Linguistic and Cultural Barriers**

The metaverse whispers the promise of a world without borders, yet language and cultural differences can still splinter connections. But fear not, this virtual realm holds the key to bridging these divides. Imagine being at a world forum in the metaverse where all of the speakers' voices instantly blend into your own tongue. Artificial intelligence (AI)-powered advanced translation systems can break down linguistic barriers and promote cross-cultural understanding and communication. Avatars themselves can develop into multilingual entities with multiple language comprehension and speech programs. This facilitates natural interactions by enabling avatars to seamlessly switch between languages, guaranteeing that no conversation is lost in translation.

However, there shouldn't be a one-size-fits-all metaverse experience. It is critical to design with cultural sensitivity. Picture virtual worlds with a wide range of architectural styles, a huge selection of avatar clothes, and virtual holidays honoring other cultures. Everyone feels heard and represented in this way. Not to be overlooked is the importance of nonverbal cues in communication. Body language, gestures, and facial expressions are still effective communication tools despite linguistic barriers [15].

These are tools that avatars can use to communicate intentions and feelings, leading to a more intuitive understanding across cultural boundaries. Even immersive learning can be conducted on the metaverse. Envision perusing digital galleries filled with priceless cultural artefacts or engaging in interactive language learning sessions where virtual characters rehearse speaking in authentic situations. Language and cultural boundaries could be broken by the metaverse if these ideas are adopted. It has the potential to become a real global village, promoting relationships and comprehension on a scale never seen before. In this virtual environment, people can communicate freely, appreciate cultural diversity, and create a social fabric that is richer and more inclusive for everyone [15].

- **Platforms and Instruments for Collaboration in Virtual Teams**

The metaverse presents a revolutionary platform for virtual teams to collaborate in innovative ways. Here's a glimpse into the tools and instruments that will shape teamwork in this exciting new frontier.

Shared workspaces and virtual whiteboards: Consider brainstorming sessions where team members from different parts of the world may instantly scribble ideas on a virtual whiteboard. These interactive areas enable visual cooperation, which promotes idea-sharing and innovative problem-solving [16].

3D Modeling and Prototyping Tools: Product development gains access to a new dimension through the metaverse. Teams can work together to design and prototype goods by using 3D modeling tools available in the metaverse. This streamlines the design process by enabling real-time feedback and iteration [16].

Immersive Project Management Tools: In the metaverse, project management has entirely new connotations. Imagine holographic screens that show crucial metrics and project timeframes, enabling team members to see progress and spot possible obstacles. By keeping everyone in sync, these immersive tools improve communication [17].

Virtual Reality (VR) and Augmented Reality (AR) Integration: Assisting on ventures in a genuinely immersive manner, virtual reality (VR) enables team members to enter 3D models and simulations. Conversely, AR enables hybrid cooperation where physical and virtual aspects merge in together by superimposing virtual components onto the real world [14].

Automation Tools and AI-Powered Assistants: Collaboration in the metaverse can be greatly streamlined with the use of artificial intelligence. AI assistants can also provide recommendations for solutions based on historical project data, automate tedious chores, and transcribe meetings. This allows human team members to concentrate on strategic thinking and innovative problem-solving, saving up crucial time [18].

5 Trust and Relationships

- **Building Trust in the absence of Physical Presence**

A world without embraces can make trust feel unattainable, even yet the metaverse beckons with the promise of connection. Trust is the cornerstone of any relationship. Authenticity is the key. Avatars allow one to express oneself, yet being genuine fosters trust. Exchanging experiences with others has great power. A sense of camaraderie is created through group activities like virtual world exploration, project collaboration, or just sipping coffee virtually. Accountability networks may also be relevant. Imagine if your avatars had verifiable histories that provided some indication of their reliability. Another layer may be added with optional confirmed IDs. Those who choose to do so may feel more trusted if you securely link your avatar to your true identity.

But deeds speak louder than appearances when it comes to trust. A trustworthy virtual citizen keeps their word, is dependable, and shows consideration for others. And last, trust develops gradually. You may connect with people and establish a foundation of trust by engaging in consistent interaction, whether it be through

friendly chats or cooperative projects. The metaverse can develop into a safe and secure environment for building relationships and trust with robust enforcement and well-defined community norms that encourage polite behavior [14].

- **Handling Conflicts and Settlements in the Metaverse**

Despite being a fascinating place, disputes can still occur in the metaverse. The secret? Good communication. Understanding the core of the disagreement requires both laying out your perspective and carefully listening. De-escalation tactics are essential since the anonymity of the metaverse can be a double-edged sword. Consider speaking in a gentler tone, indicating your tranquility using virtual emotes, or even taking a pause to collect yourself. The metaverse can benefit from having trusted individuals lead conversations towards just resolutions—mediators or arbitrators—for more complicated concerns. Alternatives that are rooted in the community may also be available, such as online town halls where citizens can discuss problems with elected officials. Systems for reporting and enforcement are also essential [19].

Bad behavior ought to be reportable by users, and repeat offenders ought to be deterred by obvious penalties (such as indefinite bans). Recall that there are other objectives besides just ending the disagreement. Seeking to mend relationships is just as vital as finding solutions [11]. Consider 16sending a virtual handshake or a conciliatory message. The metaverse can be transformed into a place where conflicts are resolved amicably and create a secure and encouraging atmosphere for all by putting these tactics into practice [].

- **The Development of Online Connections**

The metaverse is about radically changing the way we engage online; it's not only about fancy avatars and virtual landscapes. Text-based conversations give way to deeper experiences in social engagement. Authentic avatar laughter can replace emoticons because nonverbal indicators like body language and facial expressions can help establish a deeper feeling of presence and emotional connection. The boundaries of our displays are broken by the metaverse. Socializing now takes place in realistic virtual environments rather than on profiles [19].

Imagine being at a virtual concert with pals who live on the other side of the world, their avatars swaying next to you. Online relationships seem more immediate and realistic with the addition of this spatial component. Collaborative interests serve as the cornerstones of thriving communities. Imagine working together on a 3D artwork or attending a virtual book club where avatars congregate in a comfortable virtual library. These common experiences create enduring relationships and a feeling of inclusion in the metaverse. Boundaries begin to dissolve. Location and language become less of a barrier [16].

Even though it's still developing, the metaverse has a lot of potential for how people will connect in the future. It's a place where relationships go beyond the tangible, encouraging a feeling of presence, common experiences, and a better comprehension of both ourselves and other people in this enormous digital universe [16].

6 Social Influence and Impact

- **Influencers and Social Networks and their Power**

Virtual social dynamics in the metaverse are greatly influenced by influencers and social networks. Influencers can reach audiences across vast digital landscapes by amplifying their impact through various platforms. By bringing people together via common interests and experiences, they create communities that go beyond geographic limits. Since they select experiences and affect consumption habits, content creation is a key component of their impact in the metaverse. A vibrant digital economy is fuelled by the abundance of monetization opportunities, which range from brand collaborations to virtual goods sales [19].

Influencers have a cultural impact and direct the development of virtual communities by influencing trends and behaviours. In addition, they serve as social mediators, establishing standards and encouraging participation in their virtual spaces. Influencers are important middlemen in the metaverse whom brands can leverage to reach and engage consumers and create memorable marketing campaigns. The landscape of virtual social interaction and digital culture will undergo a fundamental shift as the metaverse develops, owing to the growing power of social networks and influencers. Their presence highlights how the metaverse, where digital identities and interactions reshape the parameters of social influence and connection, can revolutionize [20].

- **Trends and Viral Content in Online Communities**

Trends and viral content influence the metaverse's digital environment, promoting community involvement and increasing engagement. Content can travel quickly throughout virtual communities thanks to its integrated social networks, gaining popularity and quickly reaching a sizable audience. Immersion experiences, like virtual events and interactive games, grab users' interest and make material more likely to become viral by offering captivating settings for sharing and exploration. These trends are mostly driven by online communities within the metaverse, where users collaborate and contribute to the creation and sharing of material. Furthermore, trends frequently spread beyond the metaverse and effect regular social media platforms as well as vice versa, strengthening their influence throughout digital ecosystems [12].

Viral material, trends, and cultural artifacts all influence and reflect cultural norms and preferences, adding to the metaverse's developing digital culture. To increase their relevance and resonance in online communities, brands actively participate in these trends. They then use data-driven insights to adjust their tactics and maintain their competitive edge in the cutthroat digital market. For people and businesses looking to prosper in the dynamic and always changing metaverse, understanding and utilizing the power of trends and viral content is crucial [12].

- **Using Social Capital to Advance Both Personally and Professionally**

Leveraging social capital can have a significant impact on one's ability to progress both personally and professionally in the metaverse and in social interactions. In

virtual communities, social capital—which is based on networks, relationships, and trust—acts as currency, creating growth and opening possibilities. People can personally use social capital to develop deep relationships, get access to support systems, and widen their sphere of influence. People with social capital can move confidently and purposefully across the metaverse by making friends, connecting with mentors, and joining interest-based groups. Social capital is extremely useful for professional growth and advancement in the workplace. People can acquire knowledge, gain access to resources, and open up career chances by cultivating relationships with peers, industry leaders, and possible collaborators [21].

Establishing a strong social network can lead to partnerships, collaborations, and even job offers in the metaverse, as virtual interactions blur the boundaries between personal and professional worlds. In addition, social capital enhances people's professional travels by promoting knowledge exchange, idea generation, and skill development. In the dynamic and linked environment of the metaverse, people may succeed by actively participating in creating and sustaining social capital on both a personal and professional level, opening up new opportunities, and reaching their full potential [20].

7 Conclusion

"From Avatars to Allies: Understanding Social Dynamics in the Metaverse" offers a comprehensive examination of the complex web of interactions between people in virtual spaces. Avatars are used as a medium for self-expression and cultural representation as people begin the process of creating digital identities, going beyond simple customization. This procedure emphasises how important it is to have a unique identity in the metaverse, where people must negotiate intricate social and cultural relationships. Spatial awareness and following social norms and protocol become crucial in virtual environments. It takes a thorough awareness of social conventions and the development of polite relationships to navigate these digital environments. Users create restrictions and personal boundaries as they interact with the metaverse to strike a good balance between virtual and real-world experiences.

The emergence of virtual communities emphasises even more how intertwined people are in the metaverse. These communities act as centres for cooperation and group development because they are based on shared interests and are guided by inclusive values. To preserve these communities' vitality and integrity and to create an atmosphere in which diversity is valued and all opinions are heard, governance and moderation are essential. The foundations of social interaction in the metaverse are effective communication and teamwork. Communication, whether it be verbal or nonverbal, builds bridges over linguistic and cultural divides to allow meaningful relationships to grow. Furthermore, the growth of relationships and trust when there is no physical presence emphasises how crucial sincerity and empathy are to fostering online interactions.

The metaverse is shaped by influencers and social networks, who have a great impact on social impact and trends. Individuals can achieve their professional and personal objectives by utilising social capital, which adds to the overall expansion of digital culture. Encouraging meaningful connections and positive development within virtual communities are facilitated by an awareness of and acceptance of the subtleties of social dynamics that guide individuals as they navigate the intricacies of the metaverse.

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Application of Metaverse in Advertising:-Opportunities & Challenges

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Abstract Technology has been a key factor in the advertising industry's constant evolution, carrying it from one age to the next. Every technological development, from the heyday of radio and television to the emergence of the Internet and digital media, has changed how businesses interact with their target audience. These days, everyone is talking about the Metaverse. What was formerly limited to science fiction, as most famously shown in films such as The Matrix, has surpassed fiction to become a palpable reality. The word "Metaverse" itself combines the terms "verse," which denotes the universe, and "meta," which means beyond. It depicts an immersive virtual world that spans several connected three-dimensional realms and is populated by avatars, who are computer versions of actual people. scenery. As technology advances allow for more immersive digital experiences, the idea of a common virtual shared place called the Metaverse is gaining traction quickly. In this chapter, we have analyzed the potential for transformation at the nexus of the Metaverse and advertising, looking at both consumers and marketers. Agencies and strategists in digital advertising and marketing must be aware of the metaverse's possibilities and keep up with the swift developments in artificial intelligence. The fact that Gen Z and millennials, the main target audiences, are already using platforms like Rob lox and other virtual reality technology to immerse themselves in virtual worlds and engage in metaverse activities makes this especially important. The present study aims to find out the potentials of of advertising in the metaverse, possible difficulties, and viable solutions to link the virtual and physical worlds.

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List of Notations and Abbreviations

AR	Augmented Reality
VR	Virtual Reality
3D	Three-Dimensional
AI	Artificial Intelligence
BC	Before Christ
AT&T	American Telephone and Telegraph
Ads	Advertisements
CEO	Chief Executive Officer
MVRS	Metaverse Air
GUI	Graphical User Interface
MSIT	Multisensory Integration Technology
HDR	High Dynamic Range

1 Introduction

One major advantage is that the Metaverse allows businesses to connect with customers anywhere in the world, so they may reach a global audience [1]. Additionally, businesses can communicate with customers in ways that are not feasible in the real world thanks to the Metaverse's unique and interactive environment [2]. From social interactions to business operations—all within immersive 3D settings that blend gaming, social networking, education, and entertainment elements. By using the Metaverse, companies may provide their clients with immersive and interesting experiences, such as virtual events or marketplaces. The Metaverse provides a useful chance for businesses to get information about their target audiences. Utilizing this data will help you better understand consumer behavior and better target your marketing messaging. It is important to take into account any possible disadvantages, though.

As technology continues to evolve at an exponential pace, organizations face the challenge of staying relevant and adapting swiftly to rapid advancements in computer systems and technical infrastructure [3]. The Metaverse has emerged as a central topic in this context, offering capabilities for users to engage in buying and selling digital goods, meaningful social interactions, exploration of fantastical or realistically simulated environments, and much more [4]. Its potential, as highlighted by Mileva, is boundless and hinges on the creativity of its users, promising transformative possibilities in how people communicate, collaborate, and entertain themselves online.

Moreover, the Metaverse presents new avenues for individuals and businesses to interact and expand their presence in virtual realms [5]. Celebrities and notable figures are already leveraging the Metaverse to extend their brands, underscoring its potential as a powerful platform for branding and marketing initiatives [6]. However, amidst these opportunities, careful consideration of potential drawbacks is crucial before embarking on Metaverse-driven strategies. In essence, the Metaverse represents more than just a technological advancement; it signifies a shift towards increasingly interconnected and immersive digital experiences. Understanding its implications and leveraging its connectivity is key as we navigate the transformative possibilities of this emerging virtual frontier.

1.1 Metaverse-Meaning and Significance

1.1.1 Meaning

The term "Metaverse" refers to the envisioned evolution of the internet into a cohesive, immersive virtual environment, primarily facilitated by advances in augmented reality (AR) and virtual reality (VR) technology [7]. When Facebook rebranded itself as "Meta" in October 2021, CEO Mark Zuckerberg articulated his vision of the metaverse as the next phase of the internet. The term "metaverse" was first introduced by American writer Neal Stephenson in his 1992 science fiction novel *Snow Crash*. In practical terms, the metaverse is imagined as an expansive 3D virtual world where users can connect and engage in activities such as gaming, work, and social interactions using personalized avatars [8].

Connectivity is fundamental to the metaverse experience, enabling seamless interactions and the ownership of virtual assets like real estate, art, and merchandise within a digital economy with its currency. Metaverse platforms can be categorized into centralized and decentralized types. Centralized metaverse platforms are owned and operated by businesses, that manage user assets and data. In contrast, decentralized metaverse platforms leverage public blockchain technology to enable user interactions and greater autonomy through public blockchain wallets [9].

The emergence of the metaverse presents both opportunities and challenges for individuals and businesses. It opens new pathways for communication, commerce, and creative expression while raising concerns about privacy, governance, and digital rights in virtual spaces. Navigating this evolving digital landscape will require an understanding of the nuances and potential impacts of the metaverse, especially as interest and investment in this domain continue to grow.

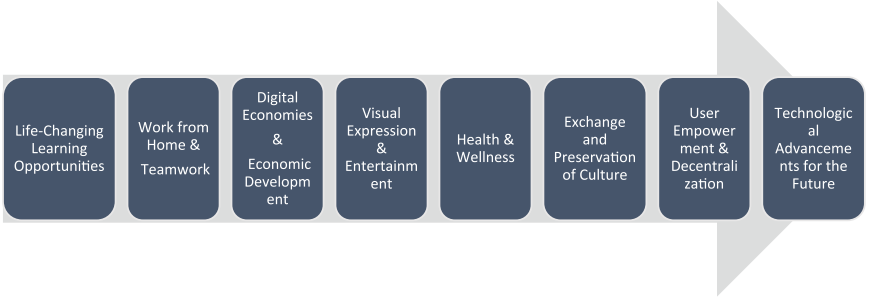

Fig. 1 Significance of Metaverse. *Source* Authors own

1.1.2 Significance

The metaverse is a game-changer for many industries, including business, interactions, and the way we view the digital world. The significance of Metaverse in general is given below (Fig. 1).

The immersive and interactive environment of the Metaverse holds the potential to revolutionize multiple industries. Virtual classrooms and three-dimensional (3D) site excursions are only two of the innovative learning and exploring avenues it offers. Growing numbers of people are working remotely, and the Metaverse provides dynamic virtual collaborative spaces that increase engagement and productivity. Additionally, the Metaverse enables a developing virtual market where users may buy, sell, and trade virtual goods including clothing, houses, and artwork. Industries committed to virtual design, development, and commerce have emerged as a result, opening up new economic prospects. It also opens doors for the creation of brand-new entertainment genres, such as virtual reality gaming and interactive storytelling, enhancing user experiences and promoting cultural awareness. The Metaverse, which offers personalized workout regimens, virtual therapy sessions, and counseling in addition to commerce and entertainment, has the potential to drastically change the healthcare industry. Ultimately, the Metaverse ushers in a new era of smoothly integrating virtual worlds into everyday life, with profound cultural and economic ramifications—a paradigm shifts in the ways that people create, communicate, and engage in a variety of businesses.

2 Significance of Metaverse in Advertising

Many questions remain unanswered, such as the effectiveness of advertising in this new environment. In the metaverse, customers can personalize their avatars to reflect their preferred color schemes and other personal details, creating a truly individualized shopping experience [10].

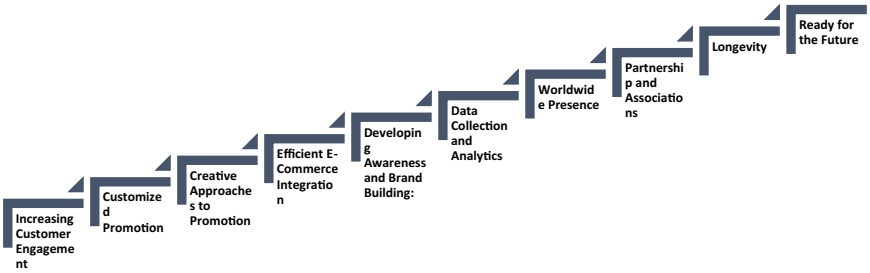

Fig. 2 Significance of Metaverse in advertising. *Source* Authors own

While it is understandable that companies are excited about the opportunity to establish creative and engaging connections with their target audiences, marketers need to remember that the principles of truth-in-advertising apply in the metaverse just as they do on social media. One feature that distinguishes metaverse advertising is the ability to create three-dimensional representations. Nonetheless, the primary goal of advertising remains unchanged: an advertising objective is any specific communication task that must be completed with a particular target audience within a set timeframe. Employer branding is an important idea in HR-marketing since it helps to establish a company's reputation as a desirable place to work. This idea is being used more and more by HR professionals to draw in, hire, and keep elite talent. Employer branding is also important in Economics and Finance since it affects employee productivity, total market reputation, and cost effectiveness [11].

The metaverse has distinctive advertising potential as a communal virtual shared space resulting from the merging of physically persistent virtual space with virtually improved physical reality.

The significance of Metaverse in the field of advertising is mentioned in the figure given below (Fig. 2).

Brands may set up events, create unique settings, and operate online storefronts to provide consumers with direct access to their products and services. With the use of virtual reality (VR) and augmented reality (AR), marketers can create engaging campaigns that meld the digital and physical worlds together. Through the use of techniques like gamification, virtual influencers, and interactive storytelling, brands can draw in audiences and cultivate a strong sense of brand loyalty. The customer journey from product discovery to purchase is streamlined and conversion rates may rise thanks to the seamless virtual shopping experience enabled by the Metaverse's interaction with e-commerce platforms.

Through the utilization of branded virtual worlds, virtual events, and exclusive digital content, brands may efficiently increase brand awareness and improve customer engagement. Furthermore, the Metaverse provides deep insights into user behavior and preferences, giving advertisers the ability to improve targeting tactics, evaluate the success of campaigns, and optimize advertising methods with the use of powerful data analytics features. Brands may effectively boost brand awareness and enhance customer engagement by leveraging branded virtual worlds, virtual events,

and unique digital content. Moreover, the Metaverse offers advertisers comprehensive insights into user behavior and preferences, enabling them to enhance targeting strategies, assess campaign effectiveness, and optimize advertising techniques through the utilization of potent data analytics tools.

Because virtual advertising in the Metaverse eliminates the need for really goods and transportation, it can complement eco-friendly marketing tactics. Compared to traditional advertising mediums, digital content creation and distribution may be done by brands with less environmental impact. Businesses may stay ahead of the curve and get ready for the future of digital engagement by making investments in the Metaverse. Because technology is developing and the Metaverse is becoming more pervasive in daily life, early adopters will have an advantage over others.

In summary, the metaverse represents a revolutionary platform for advertising, offering unparalleled opportunities for engagement, personalization, creativity, and data-driven marketing. Brands that effectively leverage the metaverse can create impactful and innovative campaigns that resonate with modern consumers.

3 Evolution of Advertising in the Digital Environment

3.1 History of Advertising

In prehistory and the Middle Ages, word-of-mouth advertising predominated. Modern advertising began in the fifteenth and sixteenth centuries with the invention of the printing press. London weekly newspapers began carrying advertisements in the seventeenth century, and by the eighteenth century, this type of advertising was booming [12].

Papyrus was used by the ancient Egyptians to make wall posters and commercial messaging. Thousands of years old, rock drawings are still in use today as a common type of commercial advertising throughout Asia, Africa, and South America. Bamboo flutes were used to promote candy in the oldest known spoken advertisement in ancient China, according to the Classic of Poetry, which was composed between the eleventh and seventh century BC. Inked paper and calligraphic signs were also widely used, and the world's first known printed advertising medium is thought to be a copper printing plate from the Song dynasty. A logo of a rabbit and the words "Jinan Liu's Fine Needle Shop" were printed on posters using this plate. We quickly prepare fine-quality needles for use at home by purchasing premium steel rods. According to Behal and Sareen [13], this is acknowledged as the first type of printed advertising in history.

People employed iconography associated with their professions to advertising their enterprises during the Middle Ages, when towns and cities grew throughout Europe and literacy rates were low. In 18th-century English weekly newspapers, ads first appeared. These early print ads, which mostly promoted books and newspapers, were made possible by advancements in the printing press [14]. Although the first

documented instances of advertising are steel paintings made by the Egyptians in approximately 2000 BC, William Caxton's printing of book advertisements that were affixed to English church doors in 1472 established the first print advertisement.

After several developments, the "father of commercial advertising," London's Thomas J. Barratt, created a very popular ad campaign for Pears soap. While employed at Pears Soap, Barratt promoted the company's goods with specific phrases, images, and slogans. "Good morning," is a well-known catchphrase of his. "Do you use Pears' soap?" was a popular question far into the twentieth century. Barratt chose English socialite and actress Lillie Langtry to represent Pears in 1882, making her the first famous person to endorse a product [15].

A significant period 1960s until the late 1980s, known as the "Golden Age of Advertising," was a time of bold concepts and well-known figures. Despite the harsh environment of the 1950s due to the Cold War, TV viewers started to feel more positive at this time. Consumer spending grew when wealth began to rebound, primarily due to modifications in advertising strategies rather than merely media selection to strengthen the bond between customers and brands, businesses started to develop enduring characters. During this period, iconic characters that may still be found on cereal boxes today were created, like Tony the Tiger for Frosted Flakes and the Snap, Crackle, and Pop gnomes for Rice Krispies. These figures supported brand identity and created a long-lasting bond with customers [16].

Advertising has a major impact on consumer behavior and brand impression in the twenty-first century. Thanks to information technology advancements, advertisements can now quickly reach a worldwide audience. Advertising has evolved with customers, becoming more original and creative as television and the internet have grown in popularity. Reaching a large number of customers has become simple and inexpensive thanks to platforms like Facebook, which has billions of members. Advertising techniques have changed as a result of accessibility, enabling more specialized and focused campaigns [17].

3.2 History of Advertising in the Digital Environment

Selling items was the primary goal of advertising, but nowadays, it emphasizes problem-solving and brand recognition. Right now, the most important question is: What problem does the consumer have, and how does the solution address it? This change in emphasis, brought about by the emergence of new media and channels, drastically altered the reasons behind advertising by placing the client rather than the product at the center of the message. Virtual and digital advertising are not new concepts, but for marketers to succeed in the metaverse, they must adopt a new approach that prioritizes user experience and creativity. Although many businesses have not yet fully explored game advertising, a few notable examples showcase the potential of metaverse advertising. For instance, through their partnership with Fortnite, players can visit the Air Jordan Museum, view branded videos, and compete in tournaments to win XI Cool Gray Sneakers. To deliver these next-generation brand

experiences, ads will need to employ more intentional and engaging strategies. A more dynamic creative approach will be required for advertising and storytelling to align with this multifaceted environment [18].

- **Introduction of Digital Advertising**

The introduction of online services like America Online and Prodigy in 1992 marked the start of the internet's popularity boom. To instantly establish a connection with consumers, marketers focused on digital marketing, specifically display advertising. Display advertising got its start in 1994 when AT&T released its first banner ad [16].

About 44% of viewers clicked through to the landing page that this banner ad directed them to. Although the page wasn't optimized, the advertisement started a revolution in the advertising sector by quickly making banner ads more and more popular. Yahoo became a for-profit company in 1995, having previously operated as an online directory. The business signed sponsorship deals with five businesses, whose logos appeared at the top of the website every day, thereby confirming the importance of digital advertising.

- **Era of Mobile Advertising**

In 2000, a Finnish news supplier gave away free SMS news headlines, which launched mobile marketing and led to the emergence of mobile advertising. This pioneering effort cleared the path for later trials and developments in mobile advertising tactics. A major turning point for mobile advertising came with the release of the first iPhone in 2007 and the general deployment of smartphones.

Marketers first only adapted their desktop advertisements for mobile devices, which led to shoddy user experiences and bad design. Advertisers were forced to reconsider their strategy and create new, mobile-specific ads in response to the overwhelming negative reception these early smartphone commercials received.

In recent years, the industrial sector has received renewed attention in the wake of the global recession. Businesses that moved operations in the past to benefit from cheaper labor are now attempting to reclaim their competitive advantage. This change entails reevaluating operational effectiveness, making investments in cutting-edge technology, and improving staff competencies in order to adjust to the evolving economic environment. Despite economic headwinds, these businesses want to fortify their market positions and spur long-term growth by emphasizing innovation and sustainability [19].

3.3 Emergence of Virtual Reality and Augmented Reality in Advertising

Throughout marketing and advertising's history, companies have consistently looked for novel approaches to connect with their target markets. At first, the internet helped them access a wider audience, but the emergence of social media gave them more

chances to interact with customers on other online platforms. The most recent development in this field is the Metaverse. Users of this virtual world can communicate in a three-dimensional setting, providing a distinctive means for companies and individuals to increase their reach and cultivate relationships [20]. According to Molina [1], there is a considerable chance that corporations will follow suit as celebrities and influencers have already accepted the Metaverse as an extension of their brands. But it's important to carefully weigh the Metaverse's possible advantages and disadvantages before utilizing it to its fullest extent for branding and marketing.

"Metaverse" is a concept that has been incredibly popular in the tech business since 2020. The term, Neal Stephenson first used in his 1992 book Snow Crash, describes a three-dimensional virtual environment where actual people communicate via avatars. Active searches on Google Trends show that interest in the Metaverse increased dramatically in 2021. Rob lox's March 10 public listing and NVidia CEO Jensen Huang's April revelation about the company's aspirations to create a Metaverse were two notable developments that aligned with this trend [21]. Also, the phrase attracted greater attention when Mark Zuckerberg, the CEO of Facebook, announced on October 28 that the firm would be renamed Meta, along with a new logo (an infinity sign) and stock ticker, MVRS [22].

- **Virtual Reality (VR)**

A sophisticated graphical user interface (GUI) called virtual reality (VR) was created to let people engage with simulated surroundings through the use of different VR devices. VR systems generate immersive 3D worlds that mirror real-world experiences in real-time by combining concepts from 3D graphics, multisensory integration technology (MSIT), and high dynamic range (HDR) display technology. Users can experience events as though they were happening in real time thanks to this level of realism. VR technology uses specialized input devices like VR headsets, motion controllers (like wands), wired gloves, body suits, and motion trackers to properly duplicate user activities in the virtual environment. Virtual reality (VR) was first welcomed by the gaming industry and has since been used to create incredibly immersive games like Second Life, Half-Life: Alyx, and Batman: Arkham VR.

Beyond gaming, virtual reality (VR) technology is progressively finding use in a variety of industries, including sports, advertising, mental health therapy, military training, medical training, and education [6]. Its capacity to provide lifelike simulations that improve training, education, and therapeutic encounters is the foundation of its efficacy in many fields, opening the door for creative uses beyond amusement.

VR is a rapidly developing medium that holds great promise for the advertising sector. In ways that frequently go beyond traditional media, it provides a singular chance to completely engross viewers in goods, brands, narratives, or locations. There are two primary categories of VR technology:

- **Interactive virtual reality**: This kind uses sophisticated computers to produce dynamic, fluid, and immersive experiences. It is designed for expensive VR headsets. Viewers can actively shape and engage with the virtual world they are immersed in using interactive virtual reality.

The way that brands interact with consumers has been completely transformed in recent years by the use of VR technology in advertising. For the first time, rather than having viewers passively watch through a screen or other passive medium, advertisers can build emotionally engaging experiences that make viewers feel physically present within a scenario [23]. The capacity to immerse spectators in virtual environments amplifies the possibilities for narrative and brand interaction. Through the use of virtual reality, marketers may create enduring impressions, elicit strong emotional reactions, and build stronger relationships with their target audience than they can with more conventional forms of advertising.

- **Immersion VR in Advertising**: Immersive VR, sometimes referred to as Cinematic VR or 360 videos, was employed by Thomas Cook, a pioneer in the travel and tourism sector with over 170 years of expertise, in a ground-breaking advertising campaign named "Thomas Cook Virtual Reality Holiday 'Try Before You Fly'." With the help of this creative campaign, Thomas Cook produced several engrossing 360 VR films that let consumers explore virtual reality vacation options and virtually visit their ideal locations. Samsung Gear VR headsets, a key campaign partner, provided access to these immersive experiences. Participants in these virtual travel experiences were encouraged to visit flagship stores located in Belgium, Germany, and the UK.

- **Augmented Reality(VR)**

Augmented reality (AR) improves the actual world by superimposing computer-generated graphics, in contrast to virtual reality (VR), which creates completely digital worlds. Niantic's Pokemon Go is one of the most well-known applications for augmented reality [24]. In this augmented reality game, users can explore their immediate surroundings and come across and catch virtual creatures known as Pokemon that are located in actual locales.

With AR interfaces, users may call up digital representations of real-world items, which appear holographic and blend perfectly with their environment. Users can scan real items and interact with them as though they were interactive and animated by using smartphones or AR smart glasses. Users can get instant access to comprehensive information about the things they view with this capability. Beyond entertainment, augmented reality's ability to seamlessly integrate digital aspects with the actual environment opens up a wide range of useful uses.

4 Opportunities and Future Challenges

By altering how businesses engage with their target audience, allocate their advertising budgets, and penetrate new markets, the metaverse has the power to drastically change advertising strategy. Understanding these changes is essential in modifying the strategies used to create and distribute marketing and advertising materials. Creating immersive experiences that redefine engagement with customers and

engagement with businesses will be the main thrust of the upcoming advertising campaigns.

The Metaverse will certainly become a major advertising platform as the Internet—and the Metaverse in particular—continues to grow. However, navigating this terrain is not without difficulties. Companies need to ensure that their presence on the relevant metaverse platforms reflects their personality, brand values, and user base. If you don't meet your customers' expectations, they may move to competitors through other channels, which will impact brand awareness, loyalty, and interactions. Because many brands have not yet entered the metaverse, advertising spend there is still reasonable, allowing visionary companies to gain a competitive advantage. As this new digital environment grows, those who put time and effort into understanding the metaverse and creating successful advertising strategies will be well-positioned for success.

In the future, studies should focus on the effects of the metaverse on society as a whole, privacy and ethical issues, the growth of consumer behavior, and cross-cultural aspects of metaverse advertising.

5 Recommendations

The hyper connectedness of the metaverse foreshadows a user population that is worldwide diversified, which complicates matters. Furthermore, there are concerns regarding potential algorithmic biases because some metaverse systems rely on artificial intelligence algorithms for management. Due to the possibility of these biases causing over-personalization and the spread of unfair content, regulatory monitoring and ethical standards are necessary to guarantee safety and fairness in virtual interactions.

Through cyber-physical systems, artificial intelligence (AI) is redefining the industrial sector by fusing the digital and physical domains with seamless integration. This development enables production to meet modern issues including customized orders, faster time-to-market deadlines, and the increasing use of sensor technology in equipment. Artificial Intelligence (AI) improves operational efficiency and agility, allowing enterprises to more precisely and quickly respond to changing market needs [19]. Companies must create thorough rules, features, and regulations that efficiently manage users' metaverse experiences to address these problems. These steps are necessary to guarantee that every user is in a polite and safe virtual environment.

6 Findings and Conclusion

It is incumbent upon marketers to acknowledge that the metaverse offers a chance to craft marketing experiences that seamlessly integrate with real-world events or replicate existing business practices. It should not be surprising that there are already

a lot of options for businesses to develop their brands and marketing strategies thanks to the metaverse. The low level of public acceptability and the limitations of current technology make it unlikely that developing, experimenting with, and succeeding in metaverse marketing will encounter major challenges.

Innovation and the range of alternatives accessible to consumers will undoubtedly increase, regardless of how the metaverse evolves in the future. The potential strategic ramifications of the metaverse for marketing, management, production, research & development, and human resources must be carefully considered by enterprises in order to generate value across the board. They have to accomplish this without depending on hype put out by the companies or the media.

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Metaverse Technological Adoption: A Study of Processes, Behaviors and Attitudes

Carolina Serras, Bráulio Alturas, and Tiago Lapa

Abstract The way we connect to the world around has undergone profound changes due to technological innovations. While these innovations have enabled greater access to information, instant communication, and opportunities for creativity, they have also given rise to issues related to health, privacy, and social isolation. The Metaverse emerges as an ambitious promise to create a virtual world in which individuals from all over the world can interact in a more immersive manner than ever before, often referred to as the future of the Internet. As technology becomes increasingly intertwined into daily lives, it becomes essential to understand the perceptions and attitudes towards these technological advances. This article aims to comprehend individuals' perceptions of current technology and its usage, as well as their perception of the creation of a truly immersive virtual world like the Metaverse. It also encompasses a literature review of the most pertinent traits of the Metaverse, formulated hypotheses based on an adapted Technology Acceptance Model (TAM), and data analysis based on an online questionnaire. The data collected was analysed using SPSS software, with the goal of capturing the current perspectives regarding the Metaverse and technological use in general. This study aspires to contribute to current research on technological adoption and perception and to offer deeper insights into the possible social impacts of technological advancements.

Keywords Perceptions of the Metaverse · Perceptions of technolog · Attitudes towards the Metaverse · Behaviors towards the Metaverse

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1 Introduction

The innate human urge to escape is as old as human history itself. From the first drawings on the walls of prehistoric caves to the initial attempts to capture moving images in 1888, humans have harbored a desire to transcend reality in an attempt, or hope, to create something beyond themselves. Human creativity stems from a longing to achieve something that does not yet exist or is not yet manifested. Creative media has been a means to "look inside a different world", as Hayao Miyazaki remarked about the birth of cinema [1]. In July of 2021, Mark Zuckerberg announced his company's rebranding to Meta, unveiling ambitious plans to construct the Metaverse. This new iteration of the Internet envisions the creation of virtual spaces facilitating unprecedented levels of interaction and connection among users.

Since Zuckerberg's announcement, many companies worldwide have chosen to invest in their own metaverses or related products, with investments spanning from north America, the greatest European and Asian economic powers, and even the United Arab Emirates [2]. However, widespread adoption of specifications for a metaverse or metaverses has yet to materialize, as each project depends on its proprietary technology [3].

Similarly to the concept of cyberspace, the notion of Metaverse also originated from science fiction. In Neal Stephenson's imaginative world of Snow Crash, individuals inhabit an alternative reality where they can access a network that leads to a second life inside a digital realm. Stephenson's depiction of the Metaverse in 1998 painted a dystopian technological landscape, inspired by the advancements he witnessed around him, primarily speculative in nature. Today, we're observing a race to the metaverse with numerous companies and individuals vying to construct digital worlds.

The transformation of the web, from static pages lacking interactivity to the emergence of Web 2.0 with social features, user-generated content, and interactivity, has profoundly impacted society. This shift, facilitated by platforms like social networks, has fostered dynamic experiences and enhanced connectivity among users [4]. Despite the advancements of web 2.0, it has faced criticism for issues related to privacy, content control, and the emergence of oligopolies [5]. Additionally, it has been linked to higher rates of depression and anxiety in young people and adults alike [6, 7].

Presently, we witness a growing embrace of the idea of Web 3.0, also referred to as the "smart web". This next phase of Internet development aims to deliver a more intelligent, decentralized, and immersive online experience. At the heart of this evolution are technologies such as artificial intelligence (AI), the Internet of Things (IoT), and blockchain, which boost user engagement and interaction [4]. The Metaverse is often linked with web 3.0, although they are distinct entities. According to Ball (2022), both are considered successors to the Internet. However, while web 3.0 doesn't necessarily mandate real-time or synchronous rendered experiences, the Metaverse doesn't inherently require decentralization, distributed databases, or blockchain technology [8].

It's crucial to emphasize that any discourse surrounding the concept of the Metaverse, as highlighted by Bibri (2022), should be examined from economic, social, political, futuristic, technological, ethical, and philosophical viewpoints [9]. However, as we witness the exponential advancement of technologies closely associated to the Metaverse—such as augmented reality (AR), extended reality (XR), mixed reality (MR), and virtual reality (VR)—which might significantly impact society—it becomes important to discuss the Metaverse within the framework of the future of technology and human interaction.

Confronted with the inevitable advent of web 3.0 and acknowledging the pervasive influence of technologies and Big Tech across all facets of society, it becomes imperative to delve into the potential human and social ramifications of an ongoing and heightened reliance on the digital realm. This exploration is essential for identifying conceivable challenges and devising corresponding solutions.

This article seeks to delve into the emergence of the Metaverse, its social impact, and its current perception in a technology-dominated society. It aims to address three main objectives: firstly, to comprehend individuals' current perceptions regarding their relationship with and utilization of the Internet and social networks; secondly, to investigate individuals' current perceptions of the concept of a fully immersive Metaverse; and thirdly, to explore potential correlations between individuals' perceptions of their technological usage and their opinions regarding the Metaverse.

2 Literature Review

2.1 Metaverse: Definitions and Concepts

The notion of Metaverse is regarded as one of the greatest technological challenges of the century [8]. Derived from the Greek *metá*, meaning "after," the term signifies posteriority and transcendence, suggesting something that surpasses conventional boundaries. As Dionisio et al. (2013, p. 6) explain, it refers to a world beyond the physical realm, not in a metaphysical or spiritual sense, but one that is digitally created [10]. The Metaverse is also often defined by various authors as a "three-dimensional" digital environment which is completely immersive and will encompass the entire Earth [11]. Authors like Bibri (2022, p. 833) and Ball (2022, p. 49), suggest that the Metaverse, created by the convergence of data-oriented technologies and immersive technologies, signifies a novel and expanded manifestation of urban spaces, that is, spaces designed and used for public or communal purposes, including social, cultural, economic, and environmental activities and aspects that shape those (virtual) spaces [9]. Spaces that have their own identity, lore, prerogatives, entities, exchanges and transactions [8].

At present, there is no clear-cut definition of the Metaverse's final form, and its definitions are rapidly evolving. Some authors view the idea of Metaverse as already manifesting in its initial developmental phases. For these authors, applications like

Second Life (2002) and the online game World of Warcraft (2004) served as early representations of a digital world or metaverse, allowing users to select avatars and interact in various ways, thus setting the groundwork for the Metaverse. Similarly, contemporary games such as Fortnite, Roblox, and Minecraft are seen as continuing this trajectory [12].

For some, the Metaverse transcends the interactive digital worlds currently observable; rather, it is an entity yet to fully materialize but actively under construction. Envisioned as an immersive and interconnected virtual realm, it is anticipated that the Metaverse will gradually encompass all planes of human activity, ranging from work to social interaction and entertainment. Others, envision it as a post-reality realm—a perpetually persistent multi-user milieu blending digital virtuality with physical reality [13]. For Bolger (2021) the Metaverse is a ubiquitous display of techno-culture poised to influence the global landscape. Initially penetrating through knowledge dissemination, then extending into the social realm, and currently advancing into the geospatial sector, Bolger envisions AI as the connective tissue binding all entities on Earth. This integration will result in a three-dimensional stratum of information and experience, facilitating a seamless transition between augmented reality (AR) and virtual reality (VR) in daily life [14]. Zuckerberg's ambitious plan also entails not only constructing a digital world but rather forging an extension of the Internet that empowers users to engage in a wide array of activities naturally, effortlessly, and intuitively.

Shortly following his initial announcement, Zuckerberg unveiled Horizon Worlds, a virtual reality platform enabling users to traverse the universe, socialize, play games, create, and engage in other interactive activities. This platform can be accessed through virtual reality equipment provided by Oculus VR, a virtual reality company. Typically, VR equipment comprises controllers for hand and arm movements and glasses that provide users with an immersive 3D experience. Subsequently, the company has invested billions in the development of VR and AR technology, aiming to realize the vision of the Metaverse. According to Meta's earnings report in October 2022, the company incurred a loss of nearly $13.72 billion [15]. More recently, in February 2023, following a 64% decline in 2022, the company's shares experienced a 27% surge, providing relief for investors. Zuckerberg's reassurance that the Metaverse will be "fundamentally important in the future" contributed to this increase, despite the ongoing high costs associated with the venture [16].

The question of whether the Metaverse can genuinely integrate into daily lives, becoming as indispensable for work and leisure as the Internet, is still under debate and will be better understood over the years. It is believed that the expansion into the Metaverse will be slow: "it will begin with consumer leisure, then advance to industry and businesses, rather than the reverse as occurred with previous waves of computing and networking" [8].

2.2 Metaverse: The Greatest Challenges

Since the turn of the twenty-first century, technology has gradually become indispensable in the daily lives of ordinary people. The significance of our connection to technology was particularly highlighted by the events of the Covid-19 pandemic in 2020, when over half of the world's inhabitants relied on technology to maintain their social, leisure, work, and educational routines. The pandemic, aside from necessitating businesses to adapt to new methods and catalyzing the digital economy at large [17] demonstrated the invaluable role of technology and its ability to support us during times of uncertainty. This period has also created an optimal environment for increased focus and investment in Metaverse related technologies. [18, 19].

Examining the technological advancements made between 2000 and 2024, it becomes evident that the world has undergone profound transformations over the span of 24 years. The rapid advancement of new technologies has outpaced society's ability to effectively regulate their impact, leading to growing concerns [20]. While technology has undoubtedly provided new opportunities for businesses, society, science, and common people, it has also initiated a period characterized by mass surveillance, inequality, and discrimination [21]. Furthermore, persistent issues such as social control, individual autonomy, cybersecurity, privacy, prejudice, and forms of social and digital exclusion continue to be perpetuated [9]. The significant rise in the usage of social networks has also brought forth issues concerning the escalation of depression, anxiety, and addictive behaviors associated with technology [6, 7]. Other issues include racism, sexism, hate speech, propaganda, psychological violence, echo chambers, demoralization, among others, which according to Chohan (2022) "risk being magnified in virtual spaces" [3].

Technology experts suggest that Metaverse technologies will likely amplify all human activities, including the challenges experienced in today's web 2.0 environment [9, 18]. Neil Postman warned of the "Faustian bargain" inherent in placing excessive trust in technology: for every benefit it offers, there is an accompanying harmful consequence - "technology giveth, technology taketh away" [22]. Regarding the Metaverse, Hirsch (2022) describes it as the "Pandora's box" of modern times, suggesting that its ambitious construction plans will introduce what are presently considered "unknown social risks" [23].

Discussing the Metaverse as a possible next progression of the Internet prompts numerous inquiries, particularly regarding its development, feasibility, transactions, societal implications, privacy, security, trust, accountability, and ownership [24]. Moreover, on a societal level, the emergence of a digital universe also raises concerns about economic access and inequality, often referred to as the "digital divide" [25]. Recognizing the potential risks associated with emerging technologies is crucial for mitigating their negative impacts. Therefore, there is a pressing need for comprehensive research into the adverse effects of technology to foster a society capable of utilizing technology productively with minimal negative consequences.

Considering this, advocating for robust regulation of the Metaverse is essential to ensure maximum safety for users and to mitigate the spread of negative associated with technological usage from outpacing technological advancements themselves.

2.3 Metaverse: The Problem with Addiction

The Metaverse has been considered a transformative technology for the near future [20]. Recent research suggests that technological advancements in social platforms, like social media, can lead to addiction among internet users. Research now points out the addictive potential of social media and the harmful outcomes it has brought and may continue to bring to both young people and adults globally [26–28].

In a 2018 study, researchers conducted a questionnaire to explore the relationship individuals have with their cell phones and concluded that there is a prevalent narrative in the media suggesting that cell phones and new technologies can be highly addictive, a narrative that influences individuals' perceptions and behaviors towards their devices [27]. Most respondents acknowledged this addictive narrative as genuine, leading to negative feelings of concern, confusion, and even defensiveness regarding their own and their loved one's interactions with smartphones [27]. The authors suggest that with this narrative of addiction becoming increasingly prevalent, and technology use becoming more widespread globally, without adequate mechanisms to address or understand this behavior, it could become deeply ingrained in society. However, they also acknowledge the complexity of defining addictive behavior, particularly in a time when much of the population integrates social media and new technologies into their daily lives, often within their professional contexts [27].

Any individual may become susceptible to various addictions based on their circumstances: if one seeks to escape from difficulties, stress, loneliness, low self-esteem, or mental health issues, the likelihood of developing an addiction increases significantly compared to someone who finds fulfillment and satisfaction in their lifestyle [29].

The question of whether Metaverse technologies could trigger addictive behaviors cannot be definitively answered; however, it is crucial to explore and acknowledge its potential for addiction. The immersive nature of Metaverse technologies can easily facilitate escapism and excessive engagement, leading to addiction. As Braud et al. (2021, p. 38) warn, excessive engagement with digital environments or user addiction is likely to become a significant concern as the Metaverse becomes more central to people's lives. Such addictions to virtual spaces can result in psychological issues and mental disorders like depression, loneliness, and increased aggression, despite widespread efforts to limit screentime [24].

What renders social networks and other applications, such as video games, addictive are elements like interactivity, a sense of reality, the possibility of escapism from offline reality, and the opportunity to immerse oneself in another "world" [28]. All these aspects could be amplified by the development of an online space like

the Metaverse. According to a 2018 study on VR addiction, it was determined that VR games can swiftly become addictive for various reasons: from their realism and intricate detail to the array of experiences they offer. Many young people reported experiencing negative symptoms when using VR, including anxiety, vision issues, attention deficits, and even physical discomfort such as headaches. Additionally, 81.82% of young participants stated that VR games could easily lead to addiction [28].

Research indicates that there is currently ambivalence in how people perceive the power of connectivity, entertainment, and information provided by technology, coupled with concerns about what cell phones and technology represent [27].

2.4 Technology Acceptance

The Technology Acceptance Model (TAM), initially proposed by Fred Davis in 1986, has emerged as one of the most generally utilized and recognized models in the study of technology reception and adoption, acknowledged for its consistency despite its limitations. Numerous studies attest to the utility of the TAM framework in examining technological acceptance [30–33].

Drawing on two preceding models developed by Fishbein and Ajzen—the Theory of Reasoned Action (TRA) in 1967 and the Theory of Planned Behavior (TPB) in 1985—Fred Davis identified three key aspects that affect user adoption of a given technology: perceived usefulness, perceived ease of use, and attitude toward use [33].

Over time, the TAM model has undergone refinement and modification to address emerging limitations, leading to the development of TAM 2 and TAM 3 extensions. The table below outlines the principal variables of the TAM model across various extensions made over time (Fig. 1).

Considering the limitations of the TAM model and the unique nature of the Metaverse as a digital realm that has yet to be fully realized, adjustments must be made to the model. This may involve eliminating variables that presuppose actual usage of the Metaverse. Additionally, for the purposes of this study, the compatibility variable introduced by Rogers in 1983 in the formulation of the DOI model—Diffusion of Innovation Theory—was taken into consideration [34].

Taking these factors into consideration, the model utilized in this research, which integrates elements from both the TAM and DOI models, is depicted in Fig. 2. The objective is to examine how specific variables influence the intent to engage with the Metaverse.

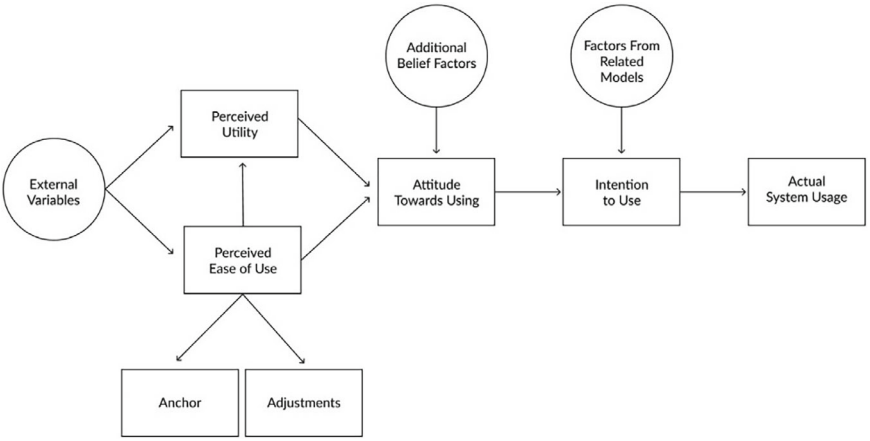

Fig. 1 The main extensions of the Technology Acceptance Model (TAM) extensively studied by Marangunić and Granić (2015)

3 Methodology

3.1 Method

This study employed online surveys to collect data necessary for addressing the research questions. The empirical data was gathered via an anonymous online questionnaire conducted on the Qualtrics platform and consisted of questions utilizing the Likert scale, as well as binary questions, aimed at assessing the attitudes and perceptions of the respondents. The target population selected consists of individuals aged 18 or older who self-reported daily Internet usage. This demographic was chosen because individuals who use the Internet regularly are presumed to have a greater familiarity with the concept of the Metaverse and online worlds compared to those who have limited or no access to the Internet [31].

The survey was structured based on previous research [31, 32, 35] and was organized into sections to streamline the data collection process. These sections included: demographic information of participants; patterns of daily technology usage; attitudes towards current technology usage; experiences with virtual reality or augmented reality elements; familiarity with virtual worlds; and perceptions of the Metaverse concept.

To gauge perceptions of the Metaverse, respondents were presented with a definition of the Metaverse, supplemented by illustrative images. The chosen definition was derived from various definitions of the Metaverse provided by authors reviewed in the literature:

> The Metaverse is currently regarded as an immersive virtual world designed to seamlessly connect all individuals and encompass a wide range of human activities, including leisure, education, socialization, and entertainment. It is envisioned as a multi-user, perpetual, and

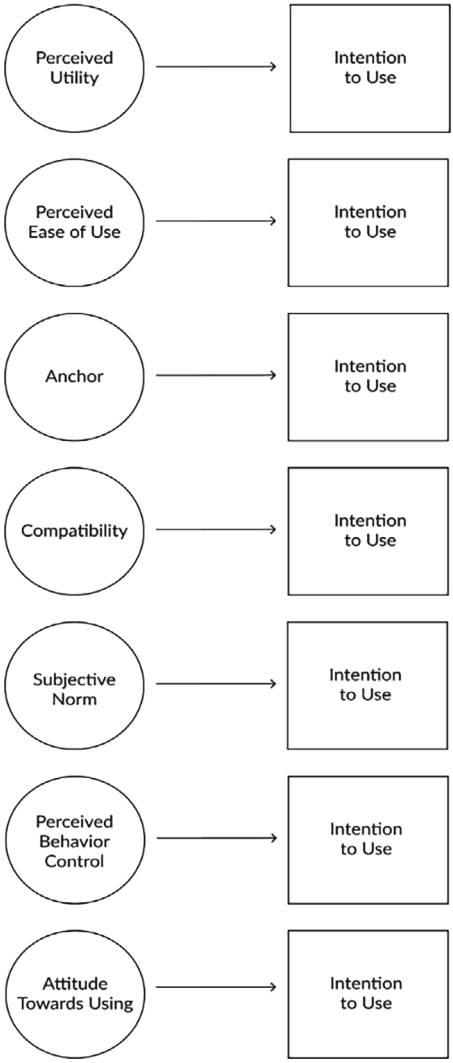

Fig. 2 The research model employed in this study inspired by the TAM model

persistent universe that blurs the boundaries between physical reality and virtual reality. Within the Metaverse, elements of extended reality (augmented reality, virtual reality, and mixed reality) are expected to be utilized intuitively and seamlessly.

To fulfill the outlined objectives and comprehend the collective perceptions of the Metaverse, research hypotheses were devised drawing from the aims of the research and the adapted TAM.

3.2 Hypotheses and Research Questions

Understanding individuals' perceptions of contemporary technology is crucial for comprehending their receptivity to future technologies. This understanding is primarily achieved by examining the connections between past and future behaviors [36].

In terms of virtual world acceptance, research in this area is still limited, however, there appears to be a correlation between how individuals perceive and utilize current technology and their willingness to accept future technologies and virtual worlds [37]. Similarly, Hua and Haughton (2009) suggest a link between regular internet usage and familiarity with virtual worlds [31], indicating that the Metaverse's acceptance and impact originate from the foundational previous technologies that enable it [38].

To address the formulated objectives, five hypotheses were formulated to be tested and either confirmed or refuted based on the obtained results.

H1: Perceived usefulness positively correlates with the intention to use the Metaverse.

Davis (p. 26) describes perceived usefulness as the degree to which a person considers that employing a particular system will improve their job functioning [39].

For our research purposes, perceived usefulness denotes the perceived level of utility that individuals associate with using the Metaverse. If potential users deem a certain technology useful, they are more inclined to embrace its usage.

H2: Perceived ease of use is positively correlated with the intention to use Metaverse.

Perceived ease of use, as defined by Davis (p. 26), refers to the degree to which a person believes that using a specific system requires no physical and/or mental effort [39].

Within the scope of this research, perceived ease of use assesses whether individuals perceive the Metaverse as user-friendly and if this perception impacts their intent to use it. While it is possible for individuals to perceive a technology as easy to use without intending to actually use it, typically both variables positively correlate with each other [40].

H3: A positive anchor is positively associated with the intention to use the Metaverse.

The anchor allows us to understand individuals' beliefs about the concept of the Metaverse. In this study, special attention is given to the notion of "computer fun," due to the crucial role that enjoyment plays in technology adoption, especially as technology becomes increasingly immersive in daily life.

The measurement of fun serves as a strong determinant of intention [41]. Metaverse's popularity of the can be assessed by examining the amount of people using VR games and other technologies considered precursors to the Metaverse [20]. Due to the voluntary nature of VR usage, it is believed that individuals with previous positive experiences in online games or other virtual worlds may be more likely to engage with the Metaverse [31].

H4: Compatibility is positively linked to the intention to use the Metaverse.

It is considered that compatibility enables the assessment of whether a particular information system aligns with an individual's usage patterns, beliefs, and lifestyle. This follows Rogers (1983, p. 15), to whom an idea that conflicts with the dominant values and norms of a social system will be adopted more slowly than an innovation that aligns with them [26].

In the context of adopting virtual worlds, compatibility concerns to the extent to which a given individual perceives the virtual world in question to be harmonious with their existing values, needs, and past experiences [31].

H5: Subjective norm is positively correlated with the intention to use the Metaverse.

Subjective norm reflects people's perception of the opinions held by those most important to them regarding a particular practice or behavior [42]. There is the assumption here that a person's behavior is significantly affected by social influence [41].

Considering the significant influence exerted by others (such as friends, family, and opinion leaders) on the adoption of behaviors or systems, the greater the interest or willingness of an individual's social circle to explore or engage with the Metaverse, the higher the likelihood of intention to use it. As noted by Fetscherin and Lattemann (2008), normative pressure to use a virtual world correlates positively with its actual usage [37].

H6: Perceived behavior control is positively correlated with the intention to use the Metaverse.

Perceived behavioral control enables the assessment of individuals' level of control and confidence in engaging in a specific behavior [43]. Ajzen (2016) indicates that higher levels of perceived behavioral control, positive attitudes and subjective norm are positively correlated with stronger intents to engage in consumer behaviors [44]. The significance of perceived behavioral control lies in the fact that individuals who feel empowered and in control of their actions have a greater tendency to consume a particular product or service [43].

In the scope of this research, perceived behavioral control concerns the level of control that individuals perceive regarding their current technological use. Given the understanding that the acceptance of virtual worlds, such as the Metaverse, is contingent upon the technology that supports their existence [38] and considering that the Metaverse emerges as a potential future evolution of the Web, it is posited here that an individual's perceived behavioral control over their current technological use will influence their intent to embrace a virtual world like the Metaverse. Consequently, a higher level of perceived behavioral control (i.e., the greater the control individuals believe they have over their behavior toward technology), is associated with greater intention to use the Metaverse, and vice versa.

H7: Attitude towards using the Metaverse is positively correlated with the intention to use the Metaverse.

Attitude represents feelings of favorability or unfavourability towards a stimulus or object—as individuals form beliefs about a particular object, they inherently develop an attitude towards it [42]. Beliefs encompass individuals' judgments

about various aspects of the world and typically serve as the foundation for attitude formation [42].

The attitude towards use pertains to the assessment (positive or negative) of a particular behavior, in this instance, the utilization of the Metaverse. Depending on individuals' varying beliefs regarding current and future technology, disparate attitudes towards the Metaverse will arise, hence different intentions of usage will be formed.

4 Findings and Discussion

4.1 Sample

To analyze the data, a quantitative study was conducted using a questionnaire distributed via Qualtrics, targeting individuals aged 18 and above who regularly use social media platforms. Qualtrics platform facilitated the statistical processing of the collected data and allowed for the conception and management of the survey with ease.

The questionnaire was distributed online from July 20 to September 7, 2023, using various channels including social media private messages, relevant online groups, and the Snowball method for selective recruitment. This sampling approach aimed to capture a diverse range of individuals with varying perceptions, usage patterns, and experiences with technology. It is important to note that convenience sampling was employed for the sampling process, indicating that the findings of this study are not generalizable.

During the dissemination period, the questionnaire garnered 163 responses, of which 40 were excluded from analysis due to a completion rate below 70%. Consequently, only 128 responses were deemed suitable for analysis.

4.2 Testing the Hypotheses

The primary statistical approach employed to test the hypotheses involves calculating Pearson's correlation coefficients (r), which quantify the strength and direction of linear relationships between quantitative factors, and that range from -1 to 1 depending on the direction of the association between the variables [45].

The statistical significance of Pearson's correlation coefficient is evaluated by comparing the p-value (Sig.) to the predetermined significance level of the test ($\alpha = 5\%$). If the p-value is less than or equal to 5%, then the Pearson correlation coefficient is considered statistically significant, as illustrated in Table 1.

Table 1 Evaluation of the hypotheses under study

Hypotheses	Correlation coefficient	Significance level
H1	Strong positive correlation r = 0,550	Statistically significant p = 0,000
H2	Strong positive correlation r = 0,694	Statistically significant p = 0,000
H3	Strong positive correlation r = 0,731	Statistically significant p = 0,000
H4	Strong positive correlation r = 0,660	Statistically significant p = 0,000
H5	Strong positive correlation r = 0,581	Statistically significant p = 0,000
H6	Weak positive correlation r = 0,172	Not statistically significant p = 0,000
H7	Moderate positive correlation r = 0,430	Statistically significant p = 0,000

5 Conclusion

5.1 Main Conclusions

This study aimed to explore individuals' attitudes and opinions towards current technology and the emerging concept of the Metaverse. Through the analysis of the questionnaire and subsequent testing of the hypotheses, several key conclusions have emerged.

Firstly, it was found that a significant portion of the population spends considerable time on the Internet and social media platforms daily for various purposes. However, more than half of the sample expressed dissatisfaction with their current level of technological engagement, indicating a desire to reduce their Internet usage. Despite widespread interest in new technological advancements, a notable proportion of respondents reported negative impacts on their health due to Internet and social media usage, including feelings of anxiety, decreased concentration and productivity, and difficulties in managing screen time.

Regarding the questions pertaining to the Metaverse, it was observed that a significant portion of respondents remained neutral, potentially indicating a lack of clarity regarding the provided definition in the survey. When queried about the positivity, excitement, fun, and usefulness of constructing a Metaverse, most respondents displayed neutral sentiments. Similarly, when assessing the necessity of the Metaverse, most respondents expressed disagreement, contrasting with their agreement on the complexity of the concept. Likewise, when asked whether the Metaverse could enhance connectivity or if it might be considered a "waste of time," the prevailing response tended towards neutrality.

Regarding experiences with virtual reality or augmented reality elements, most respondents reported having prior encounters with some of these elements, albeit with differing levels of satisfaction. Concerning the virtual worlds referenced in the questionnaire, most respondents exhibited a low level of familiarity with them.

When asked about whether the Metaverse represents greater innovation, creative opportunities, and dynamism and interaction on the Internet, most respondents agreed with these statements. However, a significant portion also expressed agreement with

the notion that the construction of the Metaverse could potentially lead to increased levels of technology addiction and a loss of sense of reality.

Regarding the likelihood of experiencing the Metaverse if it were to become accessible and the likelihood of experiencing it at least once, opinions among individuals varied. Some exhibited a strong interest in experiencing it, while others showed no interest at all. Additionally, a portion of respondents maintained a neutral stance on the matter.

It can be inferred from these findings that many of the opinion's individuals hold regarding the Metaverse are shaped by their beliefs and attitudes towards current technology and its utilization. Certain variables, like positive perceived usefulness, positive ease of use, positive anchor, positive compatibility, positive social norm, and a favorable attitude towards the Metaverse, are likely to initially influence the likelihood of its adoption. Nonetheless, these variables may constitute mere indications and not necessarily align precisely with reality. Moreover, the neutral responses elicited from respondents regarding various statements about the Metaverse in the questionnaire suggest that the implications of its creation will largely depend on its design and individual usage patterns.

Future researchers are encouraged to further explore the potential consequences of utilizing technologies like the Metaverse, particularly concerning the health and well-being of individuals. A significant number of respondents expressed dissatisfaction with their current technological usage, highlighting the relevance of future investigations into the implications of more intensive and immersive technology usage, as anticipated with the advent of the Metaverse.

5.2 Study Limitations

This study is subject to several limitations that hinder the generalization of the obtained results. Firstly, the research method employed, namely the online survey, while offering certain advantages and conveniences, also presents inherent limitations. Notably, online surveys are unsuited to collect all sorts of body language, face expressions and phatic noises, along with other non-verbal data and environmental cues [46] which are crucial components of human communication that are easily captured in face-to-face interactions. Additionally, the reliance on participants' self-reported responses raises concerns regarding the quality and accuracy of the collected information [47]. Furthermore, the absence of a qualitative research approach that employs techniques such as interviews or focus groups bounds the deepness and richness of the research findings.

Another limitation pertains to the sample size, with only 128 valid responses collected. Although this constitutes a reasonable number, it may not be sufficient to allow for generalization to the entire population. Moreover, the age restriction (18 years and older) precluded the inclusion of younger individuals, who represent a demographic particularly inclined towards technological innovations.

Another limitation of the research was the duration of the empirical data collection. Given the complexity and depth of the subject matter, the time allocated for data collection and subsequent statistical analysis proved insufficient.

Moreover, in terms of methodological analysis, the study only explored associations between variables using Pearson's correlation coefficient. Given the intricate interplay among variables within the TAM model, employing causality techniques such as multiple linear regression or structural equation modeling could have provided deeper insights into individuals' interactions with technology and their perceptions of the Metaverse. Implementing these advanced techniques would have enriched our understanding of the intricate relations between several variables and their impacts on technology adoption and Metaverse acceptance.

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