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The Metaverse: Innovations and generative AI

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ABSTRACT

Today, the Metaverse consists of various platforms, including digital twins of the physical world as well as virtual and blended digital-material environments that offer immersive experiences for individual users. By going beyond solely physical or virtual realms, these platforms unlock new possibilities for exploration, experimentation, and interaction. This makes it possible to transcend the limitations of innovation processes confined to physical locations, so the Metaverse is thus poised to drive groundbreaking innovations. This article explores the Metaverse as an innovation platform, its opportunities and challenges, including the role of generative AI in it. It discusses how the Metaverse, as a collaboration, creativity, and technological platform, supports innovation potential. By embracing the possibilities and challenges offered by the Metaverse and leveraging the capabilities of generative AI within it, a future in which individuals can truly explore novel synergies between the physical and digital realms, thriving various kinds of innovations. It is crucial to achieve holistic sustainability impacts both within the Metaverse innovation platform and as its outputs.

1. Introduction

The Metaverse is an interconnected, persistent 3D virtual spatial environment, sometimes termed Web 3.0 or 4.0, encompassing real-time interactions between users, devices, and data. Scholars and other stakeholders have diverse perspectives on the Metaverse, leading to varied interpretations.

The *industrial Metaverse* for businesses integrates 3D digital twins to simulate and experiment with real-world processes, enhancing decision-making through virtual replicas of physical entities and real-time data analysis, with the rapidly growing Internet of Things (IoT) being a key component. The *enterprise Metaverse* supports collaborative work and team building across distances and provides virtual showrooms for product and service presentations. In this sphere, virtual land, goods, art, and accessories can be rented, bought, and sold. The *governmental Metaverse* offers digitized public services, allowing users to choose between physical and virtual access. It can digitize existing services or introduce new, digital-only services, facilitating public sector efficiency. The *consumer Metaverse* for people is a virtual or blended digital-material environment for social interactions with other people and digital objects to engage, play, work, and explore. With immersive images, sounds, and other sensations, it provides the Internet with a sense of place, being there with identity and digital assets (Sparkes, 2021; Mystakidis, 2022; Kshetri and Dwivedi, 2023; Schöbel and Leimeister, 2023; Tang et al., 2023; World Economic Forum 2023).

Generative AI is becoming an integrated element in the Metaverse. AI algorithms generate new outputs such as text, images, audio,

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video, and more based on the data they have been trained on. They have deep learning and imitation capabilities in natural language use. For example, generative AI chatbots generate informative and suggestive human-like responses to user input. They create real conversational situations with people in an interactive chat environment (Aydin and Karaarslan, 2023). Integrating generative AI into Metaverse creates personalized and engaging experiences based on dynamic virtual environments in which content adapts and responds to users' actions. All this enhances interactions between chatbots and humans and generates cross-domain insights. Furthermore, creating virtual-spatial 3D content, including elements, images, and sounds, will become substantially easier, thus supporting the potential for innovative interactions in the Metaverse (Lv, 2023). In early 2024, companies produced automated content generation and non-player characters for the Metaverse gaming platforms (Docomo, 2024).

As discussed later in this article, the Metaverse is highly relevant for the emergence of innovations and broader innovation processes. It transforms the way people engage with technology and how they interact simultaneously with both physical and digital realms. By being able to reach beyond purely physical-material realms and even beyond digital-virtual realms, the Metaverse unlocks possibilities for exploration, experimentation and interaction in ways never before experienced (Dwivedi et al., 2022; Mystakidis, 2022). Real-time interactions in virtual and blended environments support participants' creativity, networking and resources, which are key elements behind an innovation ecosystem (del-Corte-Lora et al., 2023). The Metaverse also supports novel practical solutions in digital entrepreneurship along development of technology, immersion and design as well as offering possibilities for new business worlds with private and public solutions, co-design and participation in collaborative spaces as well as more conventional themes of gamification and digital twins (Calandra et al., 2023).

In addition to human-to-human interactions, interactions between humans and machines, including with generative AI, play a role in this innovation-oriented Metaverse environment. There is a need to study to what extent generative AI will be relevant in triggering innovation outcomes (Dwivedi et al., 2022; Liu and Shiu, 2024; Mariani and Dwivedi, 2024). For example, generative AI poses a fundamental disruption to the traditional innovation cycle by both complementing and sometimes replacing human-led innovation. It creates, sometimes systematically implemented in hybrid human-machine teams, opportunities for innovations through idea generation and dynamic problem solving for text summarization, unconventional designs and speedy testing for product and service improvement that enable a rate of change unseen in the industrial and service sectors (Bouschery et al., 2023; RSM, 2023). By 2024, generative AI chatbots like ChatGPT have been used for idea creation and innovation prototyping (Bilgram and Laarman, 2023). Chatbot avatars can serve in innovation processes as mediators and collaborators, providing useful information, support and reflections on anything, anytime and anywhere. Material and virtual avatars and robots learn by themselves through a self-guided propose-generate-learn cycle or from other machines (Wang et al., 2023c). This learning can also be automated, accelerating the emergence of innovations.

Currently, the Metaverse with generative AI is still in the early development phase within ongoing broader global socio-technological transformations (Lee et al., 2023). The Metaverse has the potential to become a catalyst for groundbreaking innovations, surpassing many limitations of face-to-face encounters of innovation processes in physical locations. Therefore, the potential of the Metaverse regarding innovations needs to be discussed, including how innovations could be achieved within the Metaverse and in the physical material world outside of it. As discussed later in this article, Generative AI will become a key element in such innovation processes.

Referring to the state of the art of the Metaverse, one can observe how related technologies have undergone rapid evolution. Remarkable advancements have already been achieved in immersive technologies, creating a profound sense of presence, engagement, and immersion there. The forthcoming 6G networks in the 2030s are set to unleash a tremendous surge in data flow, ubiquitous connectivity, ultra-low latency, ultra-high capacity and reliability, and strict security (Tang et al., 2023), thereby enabling the realization of numerous facets of the Metaverse. The lack of substantial computational power and data transfer, particularly for hyper-analytical quantum computing, still poses significant challenges to its global expansion (Lee et al., 2023; Wang et al., 2023a).

However, despite the unknown future of the Metaverse, several countries, regions and cities worldwide are developing strategies that specifically focus on the development and use of the Metaverse. The cases include, for example, the United Arab Emirates, China, Saudi Arabia, Singapore, the Republic of Korea, and Finland, as well as Dubai, Helsinki, London, Los Angeles, New York, Seoul, and Shanghai. These strategies aim to promote advanced technologies and related businesses and administration in the respective places on which the strategies focus (Kshetri, 2023). Many of these strategies hold a vision that the Metaverse will be significant from the latter 2020s onward. It has been suggested that the Metaverse may make up to 5000–13,000 billion USD in impact by 2030 (McKinsey, 2022; World Economic Forum, 2023).

This article addresses innovation processes within the Metaverse, where innovation is characterized as creating entirely new or novel elements for a defined context. Innovation takes various forms, encompassing new products, services, processes, production or organizational methods, business models, and market expansions. This notion aligns with the early conceptualizations of innovation put forth by the esteemed innovation scholar Joseph Schumpeter (1934) and updated, for example, by the Organization for Economic Co-operation and Development in their Oslo manual in 2005 (OECD, 2005). Innovation can thus be seen as an input for better performance, a process requiring individual or collective creativity, or an output as a novel product or service (del-Corte-Lora et al., 2023). While innovation can stem from an individual, it frequently emerges through collaborative endeavors with various stakeholders focused on attaining a shared objective (Nelson, 2018). Such collaborative efforts for creativity may entail networking, partnerships, teamwork, or a combination thereof occurring at various stages of the innovation process. These interactions are crucial in translating ideas into innovations that add value to social and economic spheres (Paulus and Nijstad, 2003; Beyerlein et al., 2006).

The questions addressed in this article are as follows: What is the current state-of-the-art regarding innovation processes within the Metaverse? What opportunities and challenges regard the Metaverse as an innovation platform? How can generative AI support the Metaverse innovation platform?

Following this introduction, the article discusses theoretical approaches regarding the emergence of innovation within the context of the Metaverse. These theories shed light on how knowledge and ideas can drive innovative outcomes in virtual and blended environments, including when people venture to realms not yet discovered and collaborate more intensively with machines supported by generative AI. Drawing insights from recent academic literature and Metaverse trends envisioned by organizations and industry leaders, the remaining sections explore distinctive opportunities that the Metaverse offers, such as technology, collaboration, and creativity innovation platforms. The main focus of this article is on consumer (people's) Metaverse. The article explores the creation and use of the Metaverse innovation platform, examining its sustainability impacts and highlighting opportunities stemming from the application of generative AI. Finally, the conclusion synthesizes key findings, offering suggestions for further research topics and policy considerations.

2. Theory: the Metaverse and the innovation processes and platforms

The Metaverse itself is a significant socio-technical innovation. In the early 2020s, the Metaverse gained increasing interest across various domains, including technology, gaming, social media, and finance (Mystakidis, 2022). Furthermore, there has recently been a rapid rise in the number of peer-reviewed academic articles on the Metaverse, with thousands of publications annually, indicating a growing interest in the topic (Anon 2). However, the potential of the Metaverse to support the emergence and development of innovations has received limited academic or applied attention thus far. The lack of such emphasis can be attributed to several factors.

First, as mentioned, a fully established overall definition for the Metaverse is lacking (Mystakidis, 2022; Dolata and Schwabe, 2023). This poses a challenge in determining the specific setting that should be explored when considering it as a potential platform for innovation. It is unlikely that in the future, there will be only one Metaverse except if it is used as a concept to cover all different digital-virtual immersive platforms.

Second, most research on the Metaverse has primarily concentrated on its technological aspects, delving into its intricacies and underlying technical infrastructure (Park and Kim, 2022), or speculating about its future. However, there has been limited exploration of Metaverse's potential for innovations beyond its technological components (Hollensen et al., 2023).

Third, as the realization of a unified Metaverse remains uncertain and even unlike, various digital platforms developed thus far have focused primarily on specific domains such as digital gaming and other entertainment in the consumer Metaverse, as well as the creation of digital twins as digitally constructed replicas of the physical world entities in the industrial Metaverse (Aloqaily et al., 2022). These gaming, working, entertaining and consuming platforms, such as CryptoVoxels, Decentraland, Fortnite, High Fidelity, Meta Horizon Worlds, Metropolis, Microsoft Mesh, NeosVR, Nvidia Omniverse, Roblox, Simulacra, Somnium Space, The Sandbox, Upland, and VRChat, to name a few, have been predominantly examined within the context of their specific use cases, rather than being considered broader catalysts or barriers for innovation in a more comprehensive Metaverse ecosystem.

Fourth, since late 2022, generative AI has overshadowed the Metaverse in public and private interest, notably after OpenAI released its ChatGPT-3.5. Subsequent advancements in tools such as Meta's Llama, Google's Gemini, and Microsoft's Copilot, alongside image and animation creators like DALL-E, Midjourney, and DeepBrain, have broadened generative AI's appeal. Google searches for "ChatGPT" have vastly outnumbered those for "Metaverse" each month since December 2022, with interest in the Metaverse decreasing by half by 2023. By mid-May 2023, searches for "generative AI" consistently surpassed those for the Metaverse, with a single exception in October 2023 (Google Trends, 2024). In contributing to this perception of the Metaverse's slowed development, Meta, Inc., a significant Metaverse advocate, shifted its focus to generative AI in 2023 (Marr, 2023). Generative AI is expected to become a key component in various industries and services, including digital environments like the Metaverse.

2.1. Innovation processes through the Metaverse

Innovation is intricately woven into the fabric of the Metaverse, shaping how people engage in social activities for improved performance, drive creative processes, and bring forth new products and services as well as new modes of entrepreneurship and business (Calandra et al., 2023; del-Corte-Lora et al., 2023). The development and utilization of the Metaverse are poised to instigate broader transformations in social, economic, institutional, and behavioral realms, serving as fundamental drivers of innovation (Kochetkov, 2023). Notably, each technology introduced contributes distinctive features to users' presence within the Metaverse.

For instance, virtual reality (VR) technologies offer fully simulated virtual environments that users can explore and interact with. As explained later, such environments have potential for innovation development. Typically, VR experiences require the use of headsets or similar devices. However, the global number of headsets in use is still limited. Approximately 21.8 million VR devices were sold in 2023, when the estimated number of VR users was 171 million worldwide (Kolmar, 2023; Statista, 2023a). Therefore, only a few percent of the global population are VR users, which limits the global dimension of VR-based Metaverse and its use for innovation processes among the wider population.

On the other hand, augmented reality (AR) technologies merge physical and digital worlds by overlaying digital content onto real-world views. Although AR is less immersive than VR and not a core part of the Metaverse, it introduces a unique blend of material and digital experiences. Through specialized headsets, smartphones, or computers, AR has reached broad audiences with applications such as Pokémon Go and is widely used in training and educational contexts. In 2023, the number of AR-capable devices reached 1.4 billion, which is significantly higher than the number of VR devices; however, these devices still do not cover the global population of 8.1 billion or 5.2 billion internet users (Statista, 2023b, 2023c). For some applications, mixed reality (MR) incorporates elements of VR and AR in a single experience.

Immersion in blended environments is critical for delivering novel experiences, as users will not return to the Metaverse if the

experience does not dramatically improve from the early 2020s (Nasdaq, 2023). In this regard, extended reality (XR) technologies play a pivotal role in Metaverse platforms. XR encompasses a variety of computer-generated hardware and software solutions that facilitate seamless transitions between a spectrum of VR and AR experiences. This capability allows for more immersive, interactive, and multi-sensory interactions with digital content. The Metaverse is expected to harness the foundations of XR, leveraging these technologies to unlock new dimensions of interaction and engagement (Stanney et al., 2021). However, certain aspects of the Metaverse can also be achieved through smartphone usage, eliminating the necessity for dedicated VR devices. Furthermore, combining generative AI and immersive technologies is expected to bring remarkable new opportunities for innovation processes in the Metaverse (Lee et al., 2023; Lv, 2023; Mariani and Dwivedi, 2024).

Inspecting innovation processes more closely, innovations do not appear from nothing, but their emergence requires the convergence of several factors. These include an idea, prior knowledge of that idea, and the iterative combination of knowledge and idea into innovation that fits into a context. Interpreting existing knowledge and novel perspectives are needed to transform ideas into innovative products, services, and solutions (Fig. 1). Collaboration, creativity, and technology are key elements of Metaverse as an innovation-supporting platform.

In a world with extended access to existing knowledge through the Internet, collaboration is increasingly required to process knowledge into ideas and further innovations. Effective interaction among stakeholders in innovation processes is facilitated by shared values, norms, attitudes, and goals. This mutual alignment encourages the free exchange of information and knowledge, fostering the necessary trust between participants to explore topics (Nilsson and Mattes, 2015) creatively. Given the inherent uncertainty in reaching innovations, trust becomes a crucial element in the process of idea generation. This underscores the significance of social dimensions in the generation of innovations (Dovey, 2009; Kochetkov, 2023).

In the past, humans were solely responsible for interpreting knowledge, either through individual experimentation or through collaboration. However, with the advent of sophisticated machines such as computers with machine learning and generative AI chatbots, innovation-related collaboration from knowledge into ideas and further toward innovations also increasingly occurs between humans and these ‘clever’ machines, including with robots and avatars, or between such machines themselves (Anon 1; Anon and Anon 3). In this context, creativity as generation or making use of new ideas with a novel approach is no longer confined to a purely human domain, as generative AI takes part in creative tasks (Amabile, 2020; Rezwana and Maher, 2022; Qin and Hui, 2023; Vinchon et al., 2023; Liu and Siau, 2024; Mariani and Dwivedi, 2024).

In the Metaverse, the innovation process becomes an interplay between the environment and human-machine collaboration in creating novel and impactful products, services, and organizational approaches within a social context. Crucial in this interactive process is that stakeholders, whether humans or machines, understand each other well enough to facilitate collaboration and creativity while maintaining a certain level of diversity. Suitable cognitive proximity fosters novel perspectives needed for achieving innovations (Anon and Anon 1; Men et al., 2020).

Human collaboration with generative AI provides highly user-centered and continuously updated solutions. Generative AI chatbots can significantly support innovation managers in processing the vast amount of information and big data needed in the innovation process. With sophisticated iterative prompting, innovation managers can ask better questions, systematically scan topics related to proto-innovation, and receive relevant answers from generative AI. It can articulate and select more challenging problems, generate concepts, and find solutions. Creative insights minimize creative blind spots in identifying opportunities for innovations (Bouschery et al., 2023; Kakatkar et al., 2020). Many tasks can be delegated to generative AI, such as ChatGPT, from ideation to early prototyping, including text summarization and sentiment analysis, to explore user perspectives and customer insights. Early tests indicated that these lead to faster iterations and reduced costs in developing innovations (Bilgram and Laarmann, 2023). The key task of humans is to understand which problems should or could be addressed (Verganti et al., 2020).

However, some scholars express skepticism regarding the ability of generative AI chatbots to effectively support innovation processes. Not all individuals trust generative AI in innovation processes, at least thus far. Many generative AI chatbots still exhibit hallucinations, providing nonsensical, unfaithful, inaccurate, or misleading information in response to given inputs. While their

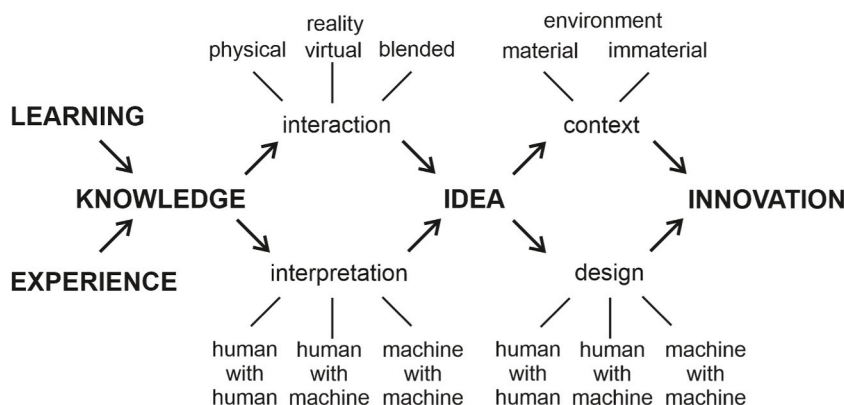


Fig. 1. Innovation processes through the Metaverse. Modified from Anon 1.

language may appear correct, the content can be false or harmful to users. Moreover, these tools are trained on databases containing biased material, producing information that users may overly rely on or misuse (Nah et al., 2023). Cybersecurity concerns also come into play, as some generative AI tools utilize users' prompts and material to further train the large language models (LLMs) upon which they are built.

In addition to being able to interpret knowledge and support idea creation, an idea needs to be transformed into innovation. This necessitates contextualization and design (Fig. 1). The contextualization of innovation can encompass physical environments in close proximity, distant geographical locations or immaterial digital environments. Presently, various digitally mediated virtual, augmented, and extended realities seamlessly blend with the physical environment in diverse combinations. This immersion in these blended environments encompasses sensory-motor, cognitive, emotional, and spatial dimensions (Björk and Holopainen, 2005). Blended environments support the transformation of ideas into innovations as they expand beyond anything experienced so far by anyone. Innovations in immersive blended environments of expanding reality (Anon 1) indicate how innovations are intrinsically coupled with the environment (Peschl and Fundneider, 2014).

Finally, design is necessary as a means through which ideas are translated into innovative tangible reality and related products and services. In this process, visual, methodological, and procedural design components synergistically function as an organizing principle that facilitates the materialization of innovations (Hernández et al., 2018). Increasingly, machine-supported design with generative AI is being utilized to augment the design process and its visualization and make it faster. Rapid advancements in open generative AI models have propelled significant strides in innovation design, particularly in the graphical and visual domains (Lv, 2023). Generative AI supported visualization regards both images and animation. However, advanced visual processing requires substantial computational power.

3. Material and methods

There is not yet a global Metaverse platform, making it challenging to empirically validate its potential for innovation. Innovations with generative AI have been scarcely addressed so far. Mariani and Dwivedi (2024) have found that academic research on generative AI in innovation studies, particularly in innovation management, is in a very early stage. In contrast, related research by industry is a little further.

Therefore, this article is based on a comprehensive review of the most recent literature, incorporating insights from several academic studies focused on combining innovation, immersive digital environments, and generative AI. Additionally, this review considers recent business trends in Metaverse development related to innovation, alongside projections regarding the integration of generative AI into the Metaverse and its anticipated effects. These projections suggest that generative AI will not only enhance the functionality and user experience within the Metaverse but also drive significant advancements in how digital platforms foster creativity, collaboration, and innovation. The main reference material is discussed in the article, also in Section 4 (for example, Duwe et al., 2022; Verganti et al., 2020; Bouschery et al., 2023; Liu and Siau, 2024; McKinsey and Company, 2022; Nah et al., 2023; Qin and Hui, 2023; RSM, 2023; World Economic Forum, 2023; Docomo, 2024; Mariani and Dwivedi, 2024). Academic materials were traced from Google Scholar, Web of Science, and Scopus with keywords including “Metaverse”, “innovation” and “generative AI”, and non-academic material was searched with Google with the same keywords. The analysis proceeded by identifying and grouping inductively the key themes that are reported and discussed in Section 4.

In addition, the exploration of theory building in this article extends to reflections from personal experiences gained through engagement with various non-gaming Metaverse platforms. These first-hand interactions have provided valuable insights into the current state of the Metaverse for innovation development, its user interface and interaction mechanisms, and the diversity of applications beyond entertainment. Through this engagement, I have observed how different platforms address user needs, facilitate interaction, and potentially contribute to broader innovation processes.

Combining a literature review, analysis of development trends, and personal exploration, this multifaceted approach aims to construct a nuanced understanding of the Metaverse's innovation capacity. It acknowledges the current limitations in global access and empirical research while recognizing Metaverse's evolving nature and the promising integration of emerging technologies like generative AI.

4. Results

Focal points in the Metaverse's capacity as an innovation platform include technology, collaboration, and creativity. Given the growing significance of generative AI in human-machine interaction and innovations, its role in shaping and utilizing this platform, as well as its implications for sustainability, warrants thorough exploration.

4.1. The Metaverse as a technology platform for innovations

The technological foundation of the Metaverse includes infrastructure and hardware (devices, systems, accessories, networks), platforms (game engines, 3D environments), enablers (payment systems, identity verification, security, and governance) and content and experiences (virtual worlds, applications) (McKinsey and Company, 2022). Technological innovations are critical as the Metaverse evolves, necessitating the development and sometimes invention of new technologies. Key areas of focus include enhancing VR, AR, and XR devices, establishing secure communication channels, data storage, financial transactions, identity verification, virtual and intellectual property protection, user reputation, and conflict resolution (Wang et al., 2023a, 2023b).

The industrial Metaverse, or digital twin technology, is being adopted worldwide across various sectors for training, design, production, and customer service. VR, AR, and XR enable immersive training and product design simulation, while machine learning analyses data for market trends and consumer behavior predictions (Aloqaily et al., 2022). These technologies reduce dependence on physical resources, speed up testing, and allow scenario exploration, improving market success chances (Singh et al., 2021). They facilitate iterative enhancements and reduce real-world experimentation risks. For consumers, the Metaverse introduces digital tools and spaces for collaboration, learning, trust, and co-creation in innovation. However, the value derived from the Metaverse varies among user profiles (World Economic Forum, 2023).

4.2. The Metaverse as a collaborative platform for innovations

Collaboration is key to innovation, and the Metaverse enables people from diverse locations to work together on innovative projects. Innovations are usually gained through collaborative endeavors when various stakeholders focus on attaining a shared objective (Nelson, 2018). VR platforms such as Horizon Worlds and Spatial support such collaboration, transcending the need for geographical proximity for effective knowledge exchange (Boshma, 2005). Establishing a shared communicative space in the Metaverse innovation platform transcends physical proximity. It allows seamless cooperation across distances, disciplines, and industries, acting as a global virtual community of practice (Dubé et al., 2006; Mystakidis, 2022). This connectivity enables the sharing and developing new ideas, products, and services worldwide. However, as a collaborative innovation platform, the Metaverse might be accessible to only a part of the global population due to existing digital divides. With an estimated 5.3 billion internet users as of 2023 and expected growth, digitalization and improved infrastructure are lowering entry barriers to the Metaverse (Statista, 2023c).

Collaboration through VR and AR offers improved co-presence over video conferencing, making remote innovation collaboration viable (Pidel and Ackermann, 2020). The immersive nature of the Metaverse enhances communication and collaborative learning, supporting knowledge co-creation for reaching innovations. People can participate in virtual events and other meetings to share ideas and learn from each other (Anon 1). They can engage in novel and inventive forms of co-creative pooling of knowledge and ideas (Dwivedi et al., 2022). This can be particularly useful for projects that require input from different skills and expertise.

With the integration of VR, AR, XR, and generative AI, the Metaverse introduces innovative communication methods that enhance collaboration and creativity. Generative AI chatbots, for instance, provide real-time idea generation as well as language translation, facilitating collaboration among diverse cultural and linguistic groups and making knowledge creation more accessible and feasible (Lv, 2023). However, as these generative AI models have been trained on biased data, the outputs might become biased against certain groups and individuals.

4.3. The Metaverse as a creativity platform for innovation

The Metaverse brings together stakeholders from diverse fields, such as science, engineering, business, design, and art, fostering interdisciplinary projects that leverage collective expertise (Dwivedi et al., 2022). Its dynamic ecosystem enables vast possibilities for interaction, engagement, and creative exploration, blurring the lines between physical and digital experiences and offering unparalleled engagement and interactivity.

Users in the Metaverse innovation platform can unleash their imaginations, explore, and create without physical or geographical constraints, inspiring creativity across various domains. A participant does not have to be limited to conversations with one's physical location and bodily extensions. This freedom, coupled with generative AI, provides a wealth of information and suggestions for innovative ideas and artistic projects (Nordström et al., 2023). Metaverse innovation platform allows individuals to explore beyond traditional boundaries, fostering immersive experiences that enhance creativity and innovation. It offers unique encounters that extend beyond current realities, promoting novel perspectives, and advancements across fields for unparalleled levels of creativity and innovation (Mystakidis, 2022). VR environments encourage divergent thinking, mental flexibility, and risk-taking, essential for creative and original idea development (Bourgeois-Bourgine et al., 2020).

The emergence of innovations in a process requires individual or collective creativity (del-Corte-Lora et al., 2023). Avatars play a crucial role in creativity and innovation-oriented collaboration within the Metaverse. Customizable avatars, enhanced by generative AI, facilitate creative communication in 3D spaces. Avatars can reflect physical appearances or imaginative creations, with distinctiveness often prioritized over realism in collaborative settings (Pidel and Ackermann, 2020). Fluid human-machine interaction in groups may be able to better address complex challenges. The Metaverse's capacity for human-machine interaction can address complex challenges, showcasing its potential for driving innovation. However, some individuals may be hesitant to use VR for sensitive discussions.

4.4. The Metaverse as an innovation platform with generative AI

As mentioned, by mid-2020, the Metaverse development will still be in a rather early phase globally. Many of its potential innovative uses are yet to be discovered. Nevertheless, it is important to carefully address challenges in making the Metaverse innovation platform possible (technical limitations, standards and interoperability, legal and ethical considerations), regarding its use as an innovation platform (trust and security, content moderation, business models) and its sustainability impacts. Generative AI will play a role in all of these processes.

4.4.1. Making of the Metaverse innovation platform

Technical limitations and challenges must be resolved to create a truly immersive and seamless Metaverse innovation platform. This requires widespread networks across multiple locations with interconnected components to handle vast data volumes and significant computational power, addressing bandwidth and latency for smooth interactions. Efficient bandwidth management and data prioritization are necessary to enhance Metaverse operations, making them more accessible by reducing hardware demands. Additionally, edge computing should be enhanced to improve Metaverse performance by reducing server strain and increasing responsiveness (Lee et al., 2023; Cai et al., 2022; Wang et al., 2023a,b,c). Advancing VR and AR technologies through research and development is crucial for developing more realistic 3D environments and enhancing user immersion.

Interoperability and standards are crucial for horizontal and vertical interworking in the Metaverse innovation platform. This would allow different platforms to interact seamlessly, as it is unlikely that there would be one universal Metaverse platform. Despite the absence of universal standards, standardized protocols and common formats can be used for effective data exchange. Several standards have been established with the aim of making interoperability possible between different Metaverse platforms (Hyun, 2023). Users establish identity through personalized avatars, a crucial tool for users' natural and technical identification. However, the diversity of Metaverse platforms complicates integration and user identity consistency, as avatars cannot migrate across virtual platforms. This lack of interoperability potentially hinders collaboration and innovation.

Legal and ethical considerations within the Metaverse innovation platform include digital ownership, virtual economies, intellectual property rights, and immersion. Zallio and Clarkson (2022) argue that a good Metaverse must embrace inclusion, diversity, equity, accessibility, and safety. This requires an affordable Internet across the world and user-friendly interfaces to bridge digital divides. However, the global nature of the Metaverse challenges state-based jurisdiction and legislation (Kalyvaki, 2023), with machine learning's opaque algorithms and data governance adding complexity. Furthermore, information asymmetries between Metaverse-related technology giants and public government regulators add challenges to the legislation process (Taeihagh et al., 2021). These global corporations establish a proprietary advantage in terms of data and algorithms that impact competition policies. It is still unclear whether generative AI is regulated differently from other forms of AI (Mariani and Dwivedi, 2024). Nevertheless, regulations can oversee virtual transactions, virtual currency exchanges, and taxation matters within the Metaverse, promoting ethical and fair financial practices and value distribution (Dwivedi et al., 2022). In the end, the Metaverse can become a decentralized and democratic virtual society with its own economic and governance system separated from individual countries' legal systems. Blockchain technology can secure digital transactions and intellectual property, with frameworks for licensing and royalty allocation supporting the rights of creators and innovators (Lee et al., 2023; Kalyvaki, 2023; Truong et al., 2023).

AI, especially generative AI, is crucial for the making of the Metaverse innovation platform. It can speed up the technical construction of the Metaverse and reduce related costs while facilitating unique and personified user experiences across different virtual environments of the Metaverse. Generative AI facilitates the creation of code for common behavior specific to a platform or used anywhere, as well as different types of creations, and improves the responsiveness and realism of common elements (Qin and Hui, 2023). This helps to adapt, translate, and standardize content across Metaverse platforms for smooth integration and supports the creation of secure, scalable virtual environments (Huynh-The et al., 2023), including automated code generation and optimization for predicted technical infrastructure uses. For example, generative AI models can be used to automate the generation of different content types belonging to the digital twin, a topic that has not been studied much so far (Qin and Hui, 2023).

Generative AI enables the creation of rich user experiences with realistic human-oriented textures, animations, and behaviors. Techniques such as procedural generation and machine learning, including supervised and unsupervised learning, are needed (Lee et al., 2023). As generative AI becomes easier and more efficient, this can lead to the democratization of content creation for the Metaverse (Qin and Hui, 2023). If needed, it can be used in developing content protection methods like watermarking and copyright detection. According to Mathieu Nouzareth, the US CEO of The Sandbox, generative AI has significantly simplified 3D modeling and content creation, allowing creators to work more creatively and efficiently. It enables the generation of diverse and realistic virtual worlds, enhancing the immersive experience of the Metaverse and fostering innovation in storytelling, gameplay, and design (Nasdaq, 2023).

4.4.2. Use of the Metaverse innovation platform

In the end, using the Metaverse innovation platform is possible when technical aspects have been solved. However, there is a need for motivation for its use. *Novel business models* are required for the economic and social relevance of the Metaverse as an innovation platform (World Economic Forum, 2023). It will offer new revenue streams for platforms, businesses, and creators in physical and digital entrepreneurship (Duwe et al., 2022; Calandra et al., 2023). Digital real estate and fashion with interactive personalized virtual assistants are already showing potential for industry transformation and disruption (Hollensen et al., 2023; Joy et al., 2022). The Metaverse also introduces innovative incentives like virtual currencies and tokens (Park and Kim, 2022) to redeem digital products for physical products and vice versa (World Economic Forum, 2023), motivating its innovative uses. However, economic risks regarding the platform include potential monopolies by dominant tech firms, limited competition and innovation, and the risk of fraud and cybercrime, which could erode trust and deter investment. The absence of a unified business model or currency complicates monetization and investment strategies for companies (Hollensen et al., 2023).

Security and user trust are key aspects of the Metaverse innovation processes. Cheng et al. (2023) argue for the need for secure authentication processes and continuous verification of users, devices, and applications without compromising the user experience. The implementation of robust security, privacy measures, and decentralized identity solutions is essential for protecting user data and maintaining privacy, especially for people and enterprises located close to users in physical or digital environments (Fernandez and Hui, 2022). Trust building in the Metaverse involves technological safeguards, clear communication, and a commitment to user safety.

Mechanisms for user reputation tracking and effective content moderation systems are necessary to ensure a safe, inclusive environment and facilitate dispute innovation-oriented resolution and community-driven governance.

Effective content moderation and clear community guidelines are essential for digitally-assisted collaboration in the Metaverse as it may face challenges, especially with the extensive user-generated content expected. It is essential to maintain a safe, inclusive space devoid of hate speech and harassment. The platform must have dispute resolution mechanisms to handle user conflicts fairly and promptly. Implementing community-driven governance, where users participate in decision-making, can enhance trust and security within the Metaverse (Fernandez and Hui, 2022; Truong et al., 2023).

AI in general and generative AI in particular can boost business, security, and trust in the Metaverse by personalizing experiences, automating content creation, and improving user engagement through tailored recommendations (Nasdaq, 2023). As discussed earlier, human-machine interaction is evidence of collective creativity that is both an input for better performance and an output of novel products and services (del-Corte-Lora et al., 2023). Generative AI can be used to easily design personalized avatars (Nasdaq, 2023) that enhance user trust and engagement in the Metaverse innovation platform. On the other hand, the presence of deepfake avatars may decrease trust. Generative AI tools can support real-time content moderation, swift harmful content identification, and enable user reports and reviews. Therefore, generative AI must be utilized for advanced encryption, anomaly detection, and user authentication to establish secure communication and transparent data handling. This facilitates personalized content recommendations that amplify engagement and revenue through tailored content and personified experiences.

4.4.3. *Impacting with the Metaverse innovation platform*

Sustainability is crucial for the Metaverse innovation platform because it impacts environmental, social, and economic aspects globally and locally. Neglecting sustainability could compromise real-world viability. Therefore, responsible digitalization is needed to transition from the physical to the virtual world (De Giovanni, 2023).

For the *environmental sustainability* of the Metaverse innovation platform, the main considerations include reducing the Metaverse's energy consumption and hardware impact. The infrastructure, such as servers, data centers and blockchain technologies, demands significant energy, potentially exacerbating climate change if not efficiently managed (De Giovanni, 2023). The adoption of energy-efficient technologies, software algorithms, and responsible hardware production and recycling is essential for mitigating environmental harm. Conversely, the Metaverse can reduce pollution and energy use by substituting virtual products for physical products and activities and lessening transport needs (Kshetri and Dwivedi, 2023). Providers should leverage renewable energy and green computing to lower carbon emissions (Lee et al., 2023). Moreover, minimizing e-waste through modular, upgradable, and recyclable Metaverse devices and optimizing data storage can further enhance environmental sustainability.

Social sustainability in the Metaverse innovation platform requires inclusivity, diversity, fairness, and openness to prevent the amplification of potential negative social issues emerging from such platforms (De Giovanni, 2023). Virtual worlds that segregate communities can lead to isolation and diminish social cohesion (Lee et al., 2023). Conversely, embracing diverse populations and perspectives fuels innovation within the Metaverse. Offering customizable avatars that reflect a wide range of appearances, body types, gender expressions, and cultural backgrounds promotes authenticity and users' belongingness. Abstract geometric forms can also represent users, offering an alternative to traditional visual representations (Anon and Anon 2). Additionally, ensuring accessibility through features like text-to-speech, closed captioning, and adjustable color contrasts is essential for enabling all individuals, including those with disabilities, to fully participate in the Metaverse.

With respect to *economic sustainability*, the Metaverse innovation platform could generate new sectors and digital goods, lessening reliance on natural resources. It promises a dynamic digital economy through virtual asset trade and immersive experiences, driving economic growth and job creation. The Metaverse enables global business engagement, transforming connectivity and supporting remote work and innovation (Hollensen et al., 2023). The Metaverse supported by generative AI is expected to have a considerable impact on the worldwide economy regarding innovation outcomes and productivity, shaping the realms of work. This will have the collateral effect of disrupting traditional economic sectors, risking sectoral displacement, unemployment, and uneven wealth distribution (De Giovanni, 2023; Liu and Siau, 2024; Mariani and Dwivedi, 2024).

Generative AI has various applications to enhance sustainability within the Metaverse, impacting environmental, social, and economic aspects. Environmentally, careful promotion can help to reduce its overall carbon footprint. It can assist in incorporating energy-efficient algorithms, promoting green data center practices, and reducing blockchain energy use. In addition, with generative AI, the deployment of renewable energy can be optimized for the Metaverse operations, the amount of waste reduced in the construction of related infrastructure and hardware and the overall quality improved so that products can be used for a longer time.

For social sustainability, generative AI can easily offer a wide range of avatar customizations (Pidel and Ackermann, 2020; Nasdaq, 2023), curating content that reflects cultural diversity and fostering community engagement and inclusivity. This creates a virtual environment that supports user accessibility, safety, and belonging and encourages participation in innovation processes from diverse backgrounds.

For economic sustainability, generative AI can speed up the creation of virtual goods and experiences through personified automation. Tailoring content based on user behavior enhances personalized engagement and revenues from such content. It also supports the development of new jobs like virtual architects, designers, and moderators, enabling these people to innovate and earn through the platform. Various forms of digital entrepreneurship will be possible (Calandra et al., 2023). Skills acquired in the virtual world—ranging from design to AI programming—translate into users' real-world job opportunities, enriching industries outside the digital domain. Additionally, generative AI can assist in streamlining transactions of virtual assets and boosting demand for real-world properties associated with virtual experiences, thereby stimulating economic growth in those areas.

5. Discussion

5.1. Theoretical implications

This article makes three major contributions to the innovation literature. First, it argues that a comprehensive re-evaluation of innovation processes is needed in the age of the Metaverse with generative AI. Innovation will manifest through an intricate interplay encompassing human-machine as well as machine-machine collaboration. Consequently, machines assume a dynamic role in supporting creativity, networking, and resources within the fabric of innovation processes and ecosystems (del-Corte-Lora et al., 2023). While human-to-human interactions also remain present, they inherently traverse the digital and technological conduit, a characteristic inherent to engagements within the Metaverse supported by generative AI.

Second, as mentioned earlier, humans can interpret knowledge and generate ideas to reach innovation (Nelson, 2018). However, this process will increasingly occur in human-generative AI collaboration (Bilgram and Laarmann, 2023; Bouschery et al., 2023; Kakatkar et al., 2020; Mariani and Dwivedi, 2024). This entails recognizing and incorporating the active involvement of machines and non-human entities in innovation theories regarding collaborative innovation processes and recognizing the creative role of machines and AI (Amabile, 2020), particularly generative AI. Chatbot avatars will be partners in the Metaverse innovation platform.

Third, a conceptual expansion of the ontological framework of reality in innovation processes is necessary in response to the advent of the Metaverse. Peschl and Fundneider (2014) suggested that innovations are intrinsically coupled with the environment. In the blended immersive Metaverse, individuals encounter places and experiences that were previously unexplored. A juncture might be reached where the conventional distinctive demarcation between the material-physical and the digital-virtual realms ceases to hold significance. As immersive digitalization advances, it becomes imperative to dig deeper into the conceptualization of this technologically facilitated expanding reality and the very genesis of innovations within it.

5.2. Implications for developers and policy makers

This article has three significant implications for developers and policymakers. Primarily, it suggests that rather than being a singular Metaverse, the evolving technological landscape is likely to comprise multiple distinct Metaverses. While the overarching term “Metaverse” encapsulates the amalgamated and immersive material-digital realm, currently, various platforms exist and will exist in the future, each providing distinct environments for user engagement. In this context, ensuring seamless accessibility of individual avatars across platforms is crucial. This would help translate to heightened prospects for innovations within the Metaverse and preserve the digital-material identity of users of the Metaverse innovation platform.

Second, there is a necessity to ensure universal access to the Metaverse, regardless of users’ economic, demographic, or geographical backgrounds. As the Metaverse is to exert a substantial influence on humanity and the planet Earth, this inclusivity is imperative for social and economic sustainability. Its genuine inclusiveness and potential as a novel innovation platform will expand beyond the usual face-to-face encounters in the physical material world. Currently, stakeholders in less developed countries remain underutilized, and innovations do not always fit into their contexts. Obviously, achieving this goal mandates meticulous ethical, legal, and security deliberations within the Metaverse.

Third, the development and utilization of the Metaverse may not compromise the pursuit of sustainable development. The construction and progression of the Metaverse must not only foster economic and social sustainability but also yield a positive environmental impact. Otherwise, the Metaverse risks merely offer a temporary digital refuge from the profound challenges of the physical world, ultimately curtailing the planet Earth’s viability for habitation. The Metaverse has the potential to serve as a crucible for innovations that effectively address and find solutions to the material world’s sustainability challenges to cultivate and achieve holistic sustainability.

5.3. Limitations and scope for further research

Given the current absence of a Metaverse boasting billions of users, and the rarity of platforms even with millions of participants, a significant portion of the article focuses on elucidating the Metaverse’s potential as a fertile ground for innovation. Consequently, a substantial portion of the suggestions and insights posited herein remain theoretical and potential, awaiting empirical validation. Further research could employ quantitative and qualitative methods on existing smaller Metaverse platforms, such as collaboration, creativity and sustainability platforms, for innovation.

Furthermore, as of 2024, generative AI is still in its nascent phases but is developing quickly. There is considerable room for advancement in the realm of human-machine interaction within innovation contexts, not to mention the uncharted terrain of machine-to-machine innovation processes. Consequently, a compelling avenue for exploration involves examining collaborations between humans and machines, including human-based and generative AI-based collaborative avatars within the Metaverse innovation platform. It is to be explored whether these novel co-creative forms and stakeholders provide opportunities to reach holistic sustainability within the Metaverse and its innovations in the material world.

6. Conclusions

This article examined the current state-of-the-art innovation processes within the Metaverse. It was found that the Metaverse has the potential as a fertile ground for innovation, and generative AI has potential contributions. Currently, the Metaverse encapsulates an

array of digital platforms spanning functional and entertainment domains, encompassing even the realm of digital twins. The Metaverse can be used as an overarching umbrella term to cover the increasing number of these digitally-related platforms. Still, so far, universal definitions, uses, or standards do not exist.

The Metaverse itself constitutes an innovation, yet its potential as an innovation platform has not garnered significant scholarly attention. However, as its evolution unfolds, it unveils a promising realm for fostering innovation, serving as a distinctive hub for technological exploration, collaboration, and creativity. The integration of generative AI stands as a promising avenue, so innovation processes within the Metaverse are poised to increasingly embrace human-to-machine collaboration and even the prospect of machine-to-machine collaboration. This evolving landscape presents an intriguing trajectory for the interplay between human creativity and machine-enabled innovation within the Metaverse and the Metaverse as an innovation platform for broader holistic sustainability.

Ethics statement

The study for the article did not include human participants, so statement on ethics approval and consent are not needed.

Declaration of competing interest

The authors declare no conflict of interest.

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References

- Aloqaily, M., Bouachir, O., Karray, F., Ridhawi, I., Saddik, A.E., 2022. Integrating Digital Twin and Advanced Intelligent Technologies to Realize the Metaverse. *IEEE Consumer Electronics Magazine*. <https://doi.org/10.1109/MCE.2022.3212570>.
- Amabile, T., 2020. Creativity, artificial intelligence, and a world of surprises. *Acad. Manag. Discov.* 6 (3), 351–354.
- Aydin, Ö., Karaarslan, E., Is, E., 2023. ChatGPT leading generative AI? What is beyond expectations? <https://dx.doi.org/10.2139/ssrn.4341500>.
- Beyerlein, M., Beyerlein, S., Kennedy, F. (Eds.), 2006. *Innovation through Collaboration*. Emerald, London.
- Bilgram, V., Laarmann, F., 2023. Accelerating innovation with generative AI: AI-augmented digital prototyping and innovation methods. *IEEE Eng. Manag. Rev.* 51 (2), 18–25.
- Björk, S., Holopainen, J., 2005. *Patterns in Game Design*. Charles River Media, London.
- Boshma, R., 2005. Editorial: role of proximity in interaction and performance: conceptual and empirical challenges. *Reg. Stud.* 39 (1), 41–45. <https://doi.org/10.1080/0034340052000320878>.
- Bourgeois-Bourgine, S., Richard, P., Burkhardt, J., Frantz, B., Lubart, T., 2020. The expression of users' creative potential in virtual and real environments: an exploratory study. *Creativ. Res. J.* 32, 55–65. <https://doi.org/10.1080/10400419.2020.1712162>.
- Bouschery, S., Blazevic, V., Piller, F., 2023. Augmenting human innovation teams with artificial intelligence: exploring transformer-based language models. *J. Prod. Innovat. Manag.* <https://doi.org/10.1111/jpim.12656>.
- Cai, Y., Llorca, J., Tulino, A., Molisch, A., 2022. Compute- and data-intensive networks: the key to the Metaverse. In: 1st International Conference on 6G Networking (6GNet), Paris, pp. 1–8. <https://doi.org/10.1109/6GNet54646.2022.9830429>.
- Calandra, D., Oppioli, M., Sadraei, R., Jafari-Sadeghi, V., Biancone, P., 2023. Metaverse meets digital entrepreneurship: a practitioner-based qualitative synthesis. *Int. J. Entrep.* <https://doi.org/10.1108/IJEBR-01-2023-0041>.
- Cheng, R., Chen, S., Han, B., 2023. Towards zero-trust security for the Metaverse. *IEEE Commun. Mag.* <https://doi.org/10.1109/MCOM.018.2300095>.
- De Giovanni, P., 2023. Sustainability of the Metaverse: a transition to industry 5.0. *Sustainability* 15 (7), 6079. <https://doi.org/10.3390/su15076079>.
- del-Corte-Lora, V., Martínez-Fernández, T., Vallet-Bellmunt, T., Roig-Tierno, N., 2023. A configurational approach to innovation performance: the role of creativity. *Int. J. Innov. Stud.* 7, 171–186. <https://doi.org/10.1016/j.ijis.2023.03.001>.
- Docomo, 2024. DOCOMO develops world's first technology utilizing Generative AI to automatically generate non-player characters in Metaverse. https://www.docomo.ne.jp/english/info/media_center/pr/2024/0116_01.html.
- Dolata, M., Schwabe, G., 2023. What is the Metaverse and who seeks to define it? Mapping the site of social construction. *J. Inf. Technol.* <https://doi.org/10.1177/02683962231159927>.
- Dubé, L., Bourhis, A., Jacob, R., 2006. Towards a typology of virtual communities of practice. *IJIKM* 1.
- Duwe, D., Zhus, M., Weissenberger-Eibl, M., 2022. Enabling the Metaverse - Whitepaper on International User Preferences, Business Models and Innovation Processes in the Metaverse. Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe. <https://doi.org/10.24406/publica-220>.
- Dovey, K., 2009. The role of trust in innovation. *Learn. Organ.* 16 (4), 311–325. <https://doi.org/10.1108/09696470910960400>.
- Dwivedi, Y., Hughes, L., Baabdullah, A., 2022. Metaverse beyond the hype: multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *Inf. Manag.* (66), 102542. <https://doi.org/10.1016/j.ijinfomgt.2022.10254>.
- Fernandez, C., Hui, P., 2022. Life, the Metaverse and everything: an overview of privacy, ethics, and governance in Metaverse. In: *IEEE 42nd International Conference on Distributed Computing Systems Workshops (ICDCSW)*, Bologna, pp. 272–277. <https://doi.org/10.1109/ICDCSW56584.2022.00058>.
- Google Trends, 2024. Search Inquiries for Words “Metaverse”, “Generative AI” and “ChatGPT” trends.google.com/trends/.
- Hernández, R., Cooper, R., Tether, B., Murphy, E., 2018. Design, the language of innovation: a review of the design studies literature. *She Ji J. Des. Econ. Innov.* 4, 249–274. <https://doi.org/10.1016/j.sheji.2018.06.001>.
- Hollensen, S., Kotler, P., Opresnik, M., 2023. Metaverse – the new marketing universe. *J. Bus. Strat.* 44 (3), 119–125. <https://doi.org/10.1108/JBS-01-2022-0014>.
- Hyun, W., 2023. Study on standardization for interoperable Metaverse. In: 25th International Conference on Advanced Communication Technology (ICACT), pp. 319–322. <https://doi.org/10.23919/ICACT56868.2023.10079642>.
- Huynh-The, T., Pham, Q., Pham, X., Thi Nguyen, T., Han, Z., Kim, D., 2023. Artificial intelligence for the metaverse: a survey. *Eng. Appl. Artif. Intell.* 117 (Part A), 105581. <https://doi.org/10.1016/j.engappai.2022.105581>. January.
- Joy, A., Zhu, Y., Peña, C., Brouard, M., 2022. Digital future of luxury brands: metaverse, digital fashion, and non-fungible tokens. *Strat. Change* 31 (3), 337–343. <https://doi.org/10.1002/jsc.2502>.
- Kakatkar, C., Bilgram, V., Fuller, J., 2020. Innovation analytics: leveraging artificial intelligence in the innovation process. *Bus. Horiz.* 63 (2), 171–181. <https://doi.org/10.1016/j.bushor.2019.10.006>.
- Kalyvaki, M., 2023. Navigating the Metaverse business and legal challenges: intellectual property, privacy, and jurisdiction. *J. Metav.* 3 (1), 87–92. <https://doi.org/10.57019/jmv.1238344>.

- Kochetkov, D., 2023. Innovation: a state-of-the-art and typology. *Int. J. Innov. Stud.* 7, 263–272.
- Kolmar, C. Zippia, 2023. 25+ Amazing Virtual Reality Statistics: the Future of VR + AR Zippia.Com. Feb. 27, 2023. <https://www.zippia.com/advice/virtual-reality-statistics/>.
- Kshetri, N., 2023. National metaverse strategies. *Computer* 56 (2), 137–142. <https://doi.org/10.1109/MC.2022.3227681>.
- Kshetri, N., Dwivedi, Y., 2023. Pollution-reducing and pollution-generating effects of the metaverse. *Int. J. Inf. Manag.* 69, 102620 <https://doi.org/10.1016/j.ijinfomgt.2023.102620>.
- Lee, L., Braud, T., Zhou, P., Wang, L., Xuo, D., Lin, Z., Kumar, A., Bermejo, C., Hui, P., 2023. All one needs to know about Metaverse: a complete survey on technological singularity, virtual ecosystem, and research agenda. *J. Latex Class Files* 14 (8) arXiv:2110.05352.
- Liu, Y., Siau, K., 2024. Generative Artificial Intelligence and Metaverse: future of work, future of society, and future of humanity. In: Zhao, F., Miao, D. (Eds.), *AI-Generated Content. AIGC 2023. Communications in Computer and Information Science*, vol. 1946. Springer, Singapore. https://doi.org/10.1007/978-981-99-7587-7_10.
- Lv, Z., 2023. Generative artificial intelligence in the metaverse era. *IEEE Cogn. Rob.* 3, 208–217. <https://doi.org/10.1016/j.cogr.2023.06.001>.
- Mariani, M., Dwivedi, Y., 2024. Generative artificial intelligence in innovation management: a preview of future research developments. *J. Bus. Res.* 175, 114542 <https://doi.org/10.1016/j.jbusres.2024.114542>.
- Marr, B., 2023. 5 amazing ways Meta (Facebook) is using generative AI. *Forbes* 2 (May).
- McKinsey & Company, 2022. Value creation in metaverse. The real business of the virtual world. McKinsey.
- Men, C., Luo, J., Fong, P., Zhong, J., Huo, W., 2020. Translating external knowledge to team creativity in turbulent environments: the role of absorptive capacity and knowledge integration. *J. Creativ. Behav.* 54, 363–377. <https://doi.org/10.1002/jocb.371>.
- Mystakidis, S., 2022. Metaverse, *Encyclopedia* 2, 486–497. <https://doi.org/10.3390/encyclopedia2010031>.
- Nah, F., Zheng, R., Cai, J., Siau, K., Chen, L., 2023. Generative AI and ChatGPT: applications, challenges, and AI-human collaboration. *J. Inf. Technol. Case Appl. Res.* 25 (3), 277–304. <https://doi.org/10.1080/15228053.2023.2233814>.
- Nasdaq, 2023. How Generative AI Can Play a Role in the Metaverse. <https://www.nasdaq.com/articles/how-generative-ai-can-play-a-role-in-the-metaverse>.
- Nelson, R., 2018. Economic from evolutionary perspective. In: Nelson, R., Dosi, G., Helfat, C. (Eds.), *Modern Evolutionary Economics: an Overview*. Cambridge University Press, Cambridge, pp. 1–34.
- Nilsson, M., Mattes, J., 2015. The spatiality of trust: factors influencing the creation of trust and the role of face-to-face contacts. *Eur. Manag. J.* 33, 230–244. <https://doi.org/10.1016/j.emj.2015.01.002>.
- Nordström, P., Lundman, R., Hautala, J., 2023. Evolving coagency between artists and AI in the spatial cocreative process of artmaking. *Ann. Amer. Assoc. Geog.* <https://doi.org/10.1080/24694452.2023.2210647>.
- OECD (Organization for Economic Co-operation and Development), 2005. *The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual*. OECD, Paris.
- Park, S., Kim, Y., 2022. A Metaverse: taxonomy, components, applications, and open challenges. *IEEE Access* 10, 4209–4251. <https://doi.org/10.1109/ACCESS.2021.3140175>.
- Paulus, P., Nijstad, B., 2003. Group creativity. An introduction. In: Paulus, P., Nijstad, B. (Eds.), *Group Creativity. Innovation through Collaboration*, pp. 3–12. <https://doi.org/10.1093/acprof:oso/9780195147308.001.0001>.
- Peschl, M., Fundneider, T., 2014. Designing and enabling spaces for collaborative knowledge creation and innovation: from managing to enabling innovation as socio-epistemological technology. *Comput. Hum. Behav.* 37, 346–359.
- Pidel, C., Ackermann, P., 2020. Collaboration in virtual and augmented reality: a systematic overview. In: De Paolis, L., Bourdot, P. (Eds.), *Augmented Reality, Virtual Reality, and Computer Graphics. AVR 2020, Lecture Notes in Computer Science*, vol. 12242. Springer, Cham. https://doi.org/10.1007/978-3-030-58465-8_10.
- Qin, H., Hui, P., 2023. Empowering the metaverse with generative AI: survey and future directions. In: 2023 IEEE 43rd International Conference on Distributed Computing Systems Workshops (ICDCSW), Hong Kong, pp. 85–90. <https://doi.org/10.1109/ICDCSW60045.2023.00022>.
- Rezwana, J., Maher, M., 2022. Designing creative AI partners with COFI: a framework for modeling interaction in human-AI co-creative systems. *ACM Trans. Comput. Hum. Interact.* <https://doi.org/10.1145/3519026>.
- RSM, 2023. Generative AI: accelerating innovation in manufacturing. <https://www.rsmuk.com/insights/building-a-competitive-environment-for-manufacturers/generative-ai-accelerating-innovation-in-manufacturing>.
- Singh, M., Fuenmayor, E., Hinchy, E., Qiao, Y., Murray, N., Devine, D., 2021. Digital twin: origin to future. *Appl. Syst. Innov.* 4 (2), 36. <https://doi.org/10.3390/asi4020036>.
- Schumpeter, J., 1934. *Theory of Economic Development*. Harvard Univ Pr., Boston.
- Sparkes, M., 2021. What is a metaverse? *New Sci.* 251, 3348. [https://doi.org/10.1016/S0262-4079\(21\)01450-0](https://doi.org/10.1016/S0262-4079(21)01450-0).
- Statista, 2023a. Volume of the VR Headsets Market Worldwide from 2018 to 2028. <https://www.statista.com/forecasts/1331896/vr-headset-sales-volume-worldwide>.
- Statista, 2023b. Number of Mobile Augmented Reality (AR) Active User Devices Worldwide from 2019 to 2024. <https://www.statista.com/statistics/1098630/global-mobile-augmented-reality-ar-users/>.
- Statista, 2023c. Number of Internet Users Worldwide from 2009 to 2022, by Region (In Millions). <https://www.statista.com/statistics/265147/number-of-worldwide-internet-users-by-region/>.
- Schöbel, S., Leimeister, J., 2023. Metaverse platform ecosystems. *Electron. Mark.* 33, 12. <https://doi.org/10.1007/s12525-023-00623-w>.
- Stanney, K., Nye, H., Haddad, S., Hale, K., Padron, C., Cohn, J., 2021. Extended reality (XR) environments. In: Salvendy, G., Karwowski, W. (Eds.), *Handbook of Human Factors and Ergonomics*, pp. 782–815. <https://doi.org/10.1002/9781119636113.ch30>.
- Taeihagh, A., Ramesh, M., Howlett, M., 2021. Assessing the regulatory challenges of emerging disruptive technologies. *Regul. Gov* 15 (4), 1009–1019. <https://doi.org/10.1111/rego.12392>.
- Tang, F., Chen, X., Zhao, M., Kato, N., 2023. The roadmap of communication and networking in 6G for the Metaverse. *IEEE Wirel. Comm. Lett.* <https://doi.org/10.1109/MWC.019.2100721>.
- Truong, V., Le, L., Niyato, D., 2023. Blockchain meets Metaverse and digital asset management: A comprehensive survey. *IEEE Access* 11, 26258–26288. <https://doi.org/10.1109/ACCESS.2023.3257029>.
- Verganti, R., Vendraminelli, L., Iansiti, M., 2020. Innovation and design in the age of artificial intelligence. *J. Prod. Innovat. Manag.* 37 (3), 212–227. <https://doi.org/10.1111/jpim.12523>.
- Vinchon, F., et al., 2023. Artificial intelligence and creativity: a manifesto for collaboration. *J. Creativ. Behav.* 1–13. <https://doi.org/10.1002/jocb.597>.
- Wang, H., Ning, H., Lin, Y., Wang, W., Dhelim, S., Farha, F., Ding, J., Daneshmand, M., 2023a. A survey on the Metaverses: the state-of-the-art, technologies, applications, and challenges. *IEEE Internet Things J.* 10 (16), 14671 <https://doi.org/10.1109/JIOT.2023.3278329>.
- Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T., 2023b. A survey on Metaverse: fundamentals, security, and privacy. *IEEE Commun. Surv. Tutorials* 25 (1), 319–352. <https://doi.org/10.1109/COMST.2022.3202047>.
- Wang, Y., Xian, Z., Chen, F., Wang, T., Wanf, Y., Erickson, Z., Held, D., Gan, C., 2023c. RoboGen: towards Unleashing Infinite Data for Automated Robot Learning via Generative Simulation, 01455v2. <https://doi.org/10.48550/arXiv.2311.01455> arXiv:2311.
- World Economic Forum, 2023. Demystifying the Consumer Metaverse. World Economic Forum with Accenture. https://www3.weforum.org/docs/WEF_Demystifying_the_Consumer_Metaverse.pdf.
- Zallio, M., Clarkson, P.J., 2022. Designing the metaverse: a study on inclusion, diversity, equity, accessibility and safety for digital immersive environments. *Telematics Inf.* 75, 101909 <https://doi.org/10.1016/j.tele.2022.101909>.