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Metaverse-Based Learning Opportunities and Challenges: A Phenomenological Metaverse Human–Computer Interaction Study

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Abstract: The Metaverse is an end-users-oriented integration of various layers of Information Technology (IT), where Human–Computer Interaction (HCI) would be the core technology. With the rapid development of IT, the Metaverse would allow users to connect, work, conduct business, and access educational resources, all in a technology-mediated environment in new interaction ways. The Metaverse can play a major role in the future of online learning and enable a rich active learning environment, where learners have the opportunity to obtain first-hand experiences that might not be accessible in the physical world. While currently there is a severe shortage in Metaverse-Learning studies, such research strands are expected to soon emerge. The main objective of this paper is to investigate challenges and opportunities for human-centric Metaverse technology in the learning sector, hence accelerating research in this field. A phenomenological research method was used, including semi-structured in-depth interviews, essays written by participants, a focus group discussion with 19 experts in the areas of HCI, intelligent interactive technologies, and online learning. The individual interviews took place in May 2022, with a focus group meeting held online in June 2022 to formulate a collective opinion of the 19 experts. Five challenges were identified for the Metaverse-Learning context: immersive design, privacy and security, universal access, physical and psychological health concerns, and governance. While the research provided suggestions to overcome those challenges, three Meta-Learning opportunities were identified: hands-on training and learning, game-based learning, and collaboration in creating knowledge. The findings of this research contribute to understanding the complexity of the online learning in the Metaverse from the Human–Computer Interaction point of view. These findings can be used to further research the Metaverse as a virtual communication environment and potential business and learning platform.

Keywords: Human–Computer Interaction; Metaverse; phenomenological research; online communities; online learning; Meta-Learning

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1. Introduction

The Metaverse creates a virtual space where users interact and exchange information in a boundless space and time environment. The Metaverse is a three-dimensional universe of multiusers, bridging the connectivity of social media with the Virtual Reality (VR) and Augmented Reality (AR) technologies, and merging physical and virtual reality where individuals can interact with each other and with online resources [1]. In 2021, the global Metaverse market was worth USD 38.85 billion and was expected to increase to USD 47.48 billion in 2022, and to USD 829 billion by 2030 [2]. Organisations are starting to assess the potential of the Metaverse and how it can be integrated within their existing business models [3]. The Metaverse was originally based on Human–Computer Interaction and was developed into an online network of virtual worlds, allowing massive multi-users' online interactions, such as multiplayer games, cooperative learning, remote work, and other applications [4]. Although the technology and infrastructure does not yet

exist to allow the development of the Metaverse virtual worlds at scale, researchers have started to investigate the societal effects, as well as issues relating to the trust, privacy, and psychological aspects of Metaverse adoption [3]. Very little research has looked at HCI challenges and applications in the Metaverse. The few existing research papers have raised some questions and controversies and have suggested that the Metaverse HCI future is not smooth [5,6].

On the other hand, with the global COVID-19 pandemic and subsequent lockdowns, more people have embraced the idea of learning and working indoors and connecting virtually [1]. On the online learning side, the pandemic resulted in the largest online movement in the history of education, where training and education providers shifted to virtual strategies, and it is believed that the adoption of such strategies will persist, and even emerge, after the pandemic [7]. Nevertheless, the existing technologies have not been able to provide a close simulation of the learning experiences offered face-to-face [8]. An elevated version of the virtual learning platform is needed to accommodate learning objectives and ensure users' high learning experience [9]. The pandemic conditions gave a huge focus on Metaverse HCI development, especially as a potential online learning platform [9]. The Metaverse can play a major role in the future of online learning and enable a rich active learning environment, where learners have the opportunity to gain first-hand experiences that might not be accessible in the physical world [10]. Having said that, little is known to date about learning opportunities and challenges on the Metaverse platform. Metaverse-Learning is a young and evolving research strand with many promising results. While the actual impact of the Metaverse will take years to evolve, however, it is definitely the next big thing to pay attention to [3].

Phenomenological research is suggested to be a suitable framework for research on user experiences, especially in novel platforms [11]. The phenomenology method is specifically utilised to investigate perceptions and expectations towards new innovations from the user's perspective [12]. There is an increasing utilization of this approach, including in education technology research focusing on user attitude towards IT innovations. Such utilisation of a phenomenological approach increases qualitative research contributions in educational technology studies in innovative learning environments [13]. This study employs a phenomenological approach to investigate the future of online learning via the Metaverse.

Based on the previously highlighted research needs, the goal of the current study is to provide insights into the Metaverse and learning from the HCI point of view. This research employs a phenomenological investigation of the application of this concept and analyses the possible future challenges and opportunities of the Metaverse as a potential online learning and training environment.

This paper begins by discussing the literature available on Metaverse learning, highlighting the lack of research in this area. This is followed in Section 2 by a discussion of the limitation of the current 2D learning environments, and the potential benefits of Metaverse-based online learning. This is followed by a detailed description of the phenomenological methodology and data collection, analysis, and presentation of the results in Section 3. Finally, the research findings and their implications are discussed in Section 4. A summary of results and research contributions are given in Section 5. Finally, the limitations of the current study and suggested future work are listed in Section 6.

2. Literature Review

2.1. Phenomenological Method in Information Systems Research

Information systems research focusing on user attitudes towards IT innovations has primarily utilised a variety of quantitative and qualitative methods to analyse data collected. While quantitative methods are most suitable in validating models and supporting causal relationships, qualitative research design allows studying the impact of new technologies on users and societies in greater depth [14]. The phenomenology method owns the strength to study perceptions and expectations towards new innovations from the user's

perspective [12,15]. Some previous works have employed a phenomenological method in innovative educational systems research. One of these studies is the work of [11], who used a phenomenological approach to investigate the user experience towards innovative education technology. The research concluded that the theoretical and methodological approach of phenomenology is uniquely useful as a framework for developing a research agenda on user experiences with new technologies and for unifying existing lines of research in novel IT areas. Phenomenology was suggested as a highly suitable approach to investigate human experiences with the Metaverse, as a new human-technology interactive phenomena [14]. In their recent study on the Metaverse, [16], reported the validity of a phenomenological approach in analysing semi-structured interviews with experienced professionals, investigating the impact of the Metaverse platform in business, namely the esports industry.

2.2. The Need for Metaverse-Based Online Learning

Online learning is increasingly becoming part of the learning experience, especially in higher education. The COVID-19 pandemic accelerated online learning trends, leading to the largest online movement in the history of education. However, the effectiveness of the current online learning environment is an open question [17]. For instance, while Open Online Courses (MOOCs) have emerged as a popular innovative platform offering open access world-class educational resources, their completion rates are substantially less than for traditional education courses [7]. On average, less than 10% of learners who sign up to an online learning environment, such as MOOCs, typically complete a course [17], with low retention reported to be a cause of low learner engagement due mainly to the current limitations of the 2D online learning platforms [7,10]. Limited ways of interaction among participants in 2D online platforms lead to learners' inactivity and low motivation [17]. These limitations could be addressed with the Metaverse 3D environments [10,18].

Metaverse spaces are expected to enable the wider application of active learner-centred strategies such as simulations and game-based learning [18]. In the Metaverse, learners would be able to experiment with equipment, and practice complex procedural and behavioural skills without the gravity of the consequences or errors in the physical world [19]. It is estimated that the Metaverse can facilitate learners' interactions with real and virtual space supported by multilayers of technologies, such as the Internet of Things, Artificial Intelligence, and machine learning [8]. Having said that, the information systems literature has not yet explored the use of the Metaverse in education [3]. Hence, there is a need for investigating HCI preferences for a future Metaverse-based online learning environment.

2.3. Human–Computer Interaction in Metaverse Research

From a Human–Computer Interaction (HCI) perspective, the technological revival of the Metaverse might generate new interaction metaphors, designs, and tools, affecting the users' experiences in this novel platform [20]. While a considerable amount of the literature has focused on the interacting with wearable devices in the Virtual Reality gaming field [21,22], studies on the Metaverse platform are still overshadowed, especially in non-gaming applications. This fact is contradictory with the expected future of the Metaverse to form the next ubiquitous computing paradigm that has the potential to transform many aspects of e-business, such as online education and remote training [10].

The current Metaverse HCI studies look at natural ways of human–computer communication, such as voice, facial expression, and movement gesture. Some early research investigated replacing computer input peripherals (keyboard and mouse) using eye path tracking in gaming Metaverse Environments [20,23]. Gaze control was found to be much more informative than mouse clicks and movement, as not only the path is detected, but also the emotional factors of the eye tracking [20]. Eye tracking was used to assess individual cognitive training developed for route learning, where the importance for immersive platforms to map geographical environments to create a sense of reality and to maximise the "being there" presence was highlighted [23].

Some of the existing Virtual Reality (VR) studies might lead future Metaverse-Learning HCI research, such as those looking at user preferences for navigations in virtual platforms. For example, [21] reported an empirical usability assessment of three VR locomotion techniques, where twenty-six participants performed a game-like task. The System Usability Scale survey, Game Experience Questionnaire, and semi-structured interviews were utilised to assess user experiences. The results indicated factors affecting user VR locomotion experiences, such as the level of psychophysical discomfort, level of immersion, perception of ease of use and familiarity, competence, and sense of effectiveness. A similar experiment was conducted by [22], assessing user experience while navigating through a VR environment using three different locomotion techniques. Effectiveness, motion sickness, presence, and user preferences were all reported as factors affecting user experience when it came to navigating through a VR environment. Both experiments gave insights on design guidelines and frameworks to guide the design of VR navigation techniques. Table 1 lists sample of Human–Computer Interaction in Metaverse studies with the research scope and contributions.

Table 1. HCI in Metaverse Research.

Research	Methodology/Sample/Scope	Results/Contributions
[16]	Phenomenological analysis performed to analyse 8 semi-structured interviews with experienced professionals to explore how esports actors perceive the business opportunities and challenges of the Metaverse as a service-scape for esports industry.	Metaverse business opportunities: ○ A new commercial space of business ecosystem, with new business connections of interdependent actors and new media services and products. ○ New possibilities for marketing by expanding business practices online in an engaging and innovative way.
[6]	An essay paper which, by referring to several articles and reports, discussed the concepts of the Metaverse and HCI and analysed their application in the video games domain.	Opportunities: The Metaverse has a pivotal role in the creation of large gaming communities and can also bring huge benefits in the education, business, and medical fields. Challenges: ○ Security issue concerning users' personal data and personal identity information. ○ Addiction to using the Metaverse, which can have physical effects (obesity and cardiovascular diseases) and psychological effects (depression and anxiety), especially for young users.
[4]	A review paper of publications concerning HCI in virtual environments, published in the proceedings of the International Conference on Cognitive Info-communications (CogInfoCom) and Its Special Issues from 2012 to 2020. A selection criterion was added: Citations number >= 10 in IEEE Xplore OR in Scopus Q1. The review paper summarised some of the results in cognitive information and communication research within the selected sample.	On the HCI side: Insights into how human cognitive capabilities can be merged and extended with the cognitive capabilities of the virtual environments, such as the use of eye path tracking instead of the computer input peripherals. On the applicability side: Insights into the use of 3D teaching and training virtual environment in providing access to quality, cost-effective, more efficient retrieval, and inventive thinking-based learning experience. On the business side, it was reported that workflow is at least 50% faster in a 3D virtual content shared environment due to more effective collaboration, increased work access to resources, and flexible work time requirement.
[3]	This study proposed a future Metaverse research agenda by combining the informed narrative from experts with various disciplinary backgrounds on many aspects of the Metaverse and its transformational impact.	Suggested Metaverse Future Research Agenda: ○ The Metaverse governance ○ Ethics ○ Safety and security ○ Acceptable behaviours ○ Privacy

2.4. Lack of Research on Metaverse HCI

The current definitions of the Metaverse would warrant a more central role for Human–Computer Interaction in the research agenda of this novel platform. The scarcity and relatively severe shortage of research in this area raised the need for a concentrated effort

to cultivate research on HCI aspects in the Metaverse and to build a research agenda in this strand. The need for a broadened focus on Metaverse research has also been recognised by others. For example, [10] highlights the importance of studying human body language and facial expression fidelity to enable effective Metaverse virtual participation in the social mixed reality, while [6] highlights the need to study the Metaverse's physical and psychological effects on a user. As a relatively new platform, major technology companies such as Microsoft, Meta, and Google have invested hundreds of millions of dollars to develop Metaverse projects and related technologies, which are at different stages of maturity [3]. These growing business interests in Metaverse-related technological developments demonstrate that there is a growing feeling that the concept of the Metaverse will be at the core of future development. Yet, research in this area is limited, namely on the way individuals are likely to interact with this extended reality, and especially with regards to how users perceive the benefits and consequences of this new technology [10].

To boost Metaverse HCI research, in 2022, various reputable international journals called for Special Issue papers in this research strand, such as:

- *International Journal of Human–Computer Interaction* Special Issue for "Advanced research in Human–Computer Interaction in the Metaverse"
- *Electronics Journal* Special Issue "Metaverse: Current Status and Future Possibilities"
- *Cyber Psychology, Behaviour, and Social Networking Journal* Special Issue "HUMANE METAVERSE: Opportunities and Challenges Towards the Development of a Humane-Centred Metaverse"
- *Transactions on Human–Computer Interaction* (THCI) Special Issue "METAVERSE"
- *International Conference on Cognitive Info-communications* (Cog-Info-Com) Special Issue: Applications of Cognitive Info-communications

This research aims to fill the big gap in Metaverse HCI research in an online learning environment. It looks at possible future challenges and opportunities of the Metaverse as a potential online learning and training virtual environment in order to enrich research on Metaverse-powered online distance education.

3. Research Method

This research follows an inductive approach, where an investigation is conducted without trying to fit the data into a pre-existing model. Based on the exploratory nature of the study and the novelty of the topic, a phenomenological research approach was selected. This approach is appropriate for understanding new technological trends and innovations [11]. Like other qualitative methods, this approach does not start with a well-formed hypothesis. Instead, it explores the perceptions of participants while suspending the researcher's preconceived assumptions about the phenomenon; hence, the results reply on the participants' own perspectives to provide insight into their motivations [24]. In the current study, a combination of data collection tools, namely, unstructured in-depth interviews, focus group, and essays written by participants are used as a form of data triangulation, to validate the collected data if it provides similar findings [11]. A focus group is an effective method following interviews, as participants interactions would create more spontaneous responses, with opportunities to discuss perceptions and ideas collected earlier in interviews.

3.1. The Sample

In a phenomenological study, in-depth interviews with up to 10 participants as a sample size is sufficient [13]. A purposive, non-probability expert sampling technique is suggested, by matching the objectives of the research along with the characteristics of the sample to select the best-fit-expert as participants for the systematic investigation [25]. Such a sampling technique helps to extract the most out of a small sample and leads to better insights and more precise research results [26]. In the current research, purposive, non-probability voluntary expert sampling was conducted. A total of 19 Information Technology, learning, and Human–Computer Interaction experts participated in the current research.

The sample included HCI, usability, user experience, interface design, web/mobile systems design, Virtual Reality, online learning, and digital marketing experts. Few participants (30%) were full-time employees at IT firms, with most of them (70%) freelancers' consultants. Males represented 68% of the sample and females represented 32%. Table 2 lists the profile of participants.

Table 2. Participants Profile.

	Demographic Variable	Count (Percentage) N = 19
Gender:	Male	13 (68%)
	Female	6 (32%)
Age:	Below 30 years old	9 (47%)
	30–35 years old	7 (37%)
	Above 35 years old	3 (16%)
Working Experience:	8–15 years	8 (42%)
	More than 15 years	11 (58%)
Working Affiliation:	Full-Time Employee	7 (30%)
	Freelancer/Consultants	12 (70%)
Specialisation:	Human–Computer Interaction	3
	Online Learning	3
	User Experience	5
	Web/Mobile Apps Developer	3
	Interface Design	3
	Digital Marketing	1
	Virtual Reality	1

3.2. The Procedures

An informed consent agreement was presented to participants at the beginning of each interview session, stating the general purpose and procedures of the research and the voluntary nature of research participation. In May 2022, unstructured in-depth interview sessions were conducting. starting with the following leading question: "How do you perceive the Metaverse-based learning platforms, in terms of Human–Computer Interaction Opportunities and Challenges currently and in the future?". Interviews continued until the saturated point was reached, that is, when interviewees provide no new perspectives on the topic. Questions were raised, such as "What's Metaverse differentiation or competitive advantage over existing online learning platform?", "What are the Metaverse design/features that facilitate achieving learning objectives?", and "What are the challenges/limitations that might restrain the applicability of (the) Metaverse-based learning platform?". Each interview lasted for 45–60 min and was recorded after receiving interviewee permission. During the interviews, the filed notes were compiled by the researcher. At the end of each session, interviewees were asked to send an email to the researcher, including an essay of their perceptions towards the phenomena under study. On the same day, the researcher sent a follow-up email to all interviewees reminding them to write the essay. Participants were requested to email back the essay within 10 days, and were advised to not concern themselves with grammar, spelling, or length of the essay. All up, 10 participants wrote the essay and send it via email before the deadline. Finally, in June 2022, an invitation was sent to the same 19 participants to join an online focus group discussion on Zoom. Of the 19 participants who were interviewed, 14 joined the online focus group. The session was moderated by the researcher and recorded after receiving participants' permission. The focus group session lasted for two hours, during which data saturation was reached.

3.3. Data Analysis

According to [27], in relation to the data analysis process in phenomenological studies, the following steps were conducted in the current study:

1- Data Bracketing: during this stage, the researcher listens repeatedly to the audio recording of each interview and reviews its field notes to develop a holistic sense of the collected data.

2- Defining units of meaning: a list of units of relevant meaning is extracted from the data and redundant units are eliminated.

3- Clustering of units of meaning to form themes: by thoroughly examining the list of units of meaning, clusters of themes are developed by grouping units of meaning together, forming significant topics, where the overlapping of clusters is expected.

4- Summarising and validating each interview: a holistic context is formed by summarising all the themes elicited from the collected data of the single interview. A validity check is conducted by returning to the interview data to determine any discrimination between the holistic context and what was cited in each interview.

5- Extracting general and unique themes and making a composite summary: steps 1 through 4, mentioned above, are performed for all the interviews, as well as the focus group session. On the other hand, the essays received from the 10 participants were analysed using thematic analysis [28]. Thematic analysis goes beyond counting phrases or words and moves on to identifying themes describing the phenomenon under investigation [28]. Identifying a theme does not necessarily yield the frequency at which a theme occurs. Ideally, the theme will occur numerous times across the dataset, but a higher frequency does not necessarily mean that the theme is more important to understanding the data. Finally, the researcher looks at the communality of themes within the interviews, focus group, and essay findings. A composite summary is written, reflecting the context from which the themes emerged from the three data collection tools.

3.4. Considerations of Validity in Phenomenological Research

Participants' check of the findings can reduce the impact of the researcher's possible subjectivity on the results [11], which is a very important issue in phenomenology. The 19 participants in the current study received via email a copy of a draft version of this paper to validate that it reflected their perspectives regarding the phenomenon that was studied. Participants were asked to review and comment on the findings and interpretations contained in the draft version of the paper. Feedback on the findings and the researcher's interpretations was received from only three participants with minor modification of the theme's wording. These modifications were made and sent back to the three participants.

4. Research Findings

Based on the communality of themes within the findings of the interviews, focus group, and essays, the following challenges and opportunities were identified as facing Metaverse-based learning and teaching platforms.

4.1. Meta-Education Challenges

4.1.1. Immersive Design

In the Metaverse, user interaction is not only with a single interface but with the entire various platforms containing increased interactivity. Hence, all interview participants agreed on the aspect of the Metaverse design challenges. *"The design of the Metaverse will be a real challenge . . . . designing a three-dimensional not limited in space is totally different from a traditional desktop or mobile two-dimensional design"*, as expressed by an interface design interviewee. The user experience expert confirmed that *" . . . traditional two-dimensional UI elements will not work in the Metaverse"*. During the focus group, the Metaverse design challenges were discussed, and consensus was reached that designers need to create an immersive platform while keeping simplicity in mind. *"Designers will aim to show everything on the screen all at once . . . . This would be frustrating to users and may cause users' cognitive overload . . . . simplicity should be kept in mind"*, as concluded by the Human–Computer Interaction expert in the focus group. It was also concluded that as users will be interacting

with each other and with digital content at the same time, the Metaverse designers must create comprehensive interfaces, as obvious as possible, to facilitate these interactions.

On the other hand, most interviewees (11 out of 19) expressed that the Metaverse design should be consistent with the real world, to minimise the uneasiness that could be caused during switching between two realities. "*Mismatch between the Metaverse design and the real world would cause anxiety in case of switching between the two realities*", as expressed by the Virtual Reality expert in the focus group. The same expert cited in his essay that "*One of the challenges of designing Virtual/Augmented Realities user interfaces is the transition from the 2D to the 3D design and vice versa . . . . design principles for the depth of volumed space should be applied*". The focus group discussion concluded that a trade-off should be kept in mind to adapt a smooth transition between the real world and a virtual environment consistent with this real world. Because the Metaverse is still in its early design stages, designs must be flexible and adaptable as the Metaverse evolves.

4.1.2. Privacy and Security

Most interviewees (12 out of 19) raised the concern that user privacy and data security would be the limiting factors of adoption of Metaverse applications, especially in business. "*Privacy and security have always been important issues in interacting with technology . . . in the context of intelligent environments, these two issues are crucial*", as cited by a mobile application developer interviewee. *"Although the Metaverse makes us step into a revolutionary future, however, as individuals, we need to ensure that we create a safe environment for everyone"*, as cited by a user experience interviewee. A Human–Computer Interaction interviewee discussed the contradicting concepts of openness versus privacy in virtual realities. "*The level of users' privacy rights . . . the contradicting concepts of openness versus privacy will have important implications for the future and adoption of Metaverse and would determine if it can become a mainstream in e-learning"*, as quoted by the interviewee. It is worth mentioning that previous research highlighted the data security and safety issues in the Metaverse [3,6]. According to [29], the Metaverse can collect far more sensitive information than traditional systems, via headsets with live microphones and cameras and eye trackers, and this can significantly violate user privacy.

Consensus was reached within the focus group participants that the Metaverse is being built on many layers of advanced technologies, and such an increasing number of layers and complexity of technologies would amplify potential cybersecurity vulnerabilities. Recommendations were given, such as learners should be in control of their data privacy, should be able to specify what data is collected, and be able to determine what data could be shared with other learners, with the educator, and with third parties. The Metaverse should guarantee data in terms of protection of databases from theft or damage. Experts in the focus group concluded that it is a joint responsibility between the educational platform and the learner. While security awareness should be raised in individuals and institutions, the Metaverse should account for privacy and confidentiality of sensitive and personal data of learners and business, and this also address ethical concerns regarding data ownership and management.

4.1.3. Universal Access

The concept of universal access was discussed in the focus group as the accessibility and usability of technologies and a wide variety of services and activities of daily life by anyone, anywhere, anytime. With the expected technological complexity of the Metaverse, accessibility of such a high-tech platform could be a question mark, namely in technologically developing societies and for vulnerable users. "*The high cost of Metaverse equipment would be the main barrier to its mass adoption world-wide*", as expressed by an interviewee. On the other hand, reliable, high-speed, and high bandwidth Internet connections are currently required for seamless learning experience and content streaming, which might not be available in some technologically developing countries. Consensus was reached in the focus group that since new technologies in general are designed to the

quality of life of various populations, these technologies should be designed for public interactions and should address the escalated accessibility needs, pertaining to each device and service, and avoid focusing on tech-savvy generations. "*A main challenge of Metaverse adoption is the generation gap between its users*", as cited by an interview participant. The same participant elaborated more in his essay that " . . . *Generations born prior the digital age, and even generation Y born in the decades of the 80s and 90s and are considered the first digital natives, all might face a real challenge communicating in the Metaverse. This might not apply for generation Z, those born during the present millennium and tend to be impatient and self-learning oriented due to their intensive use of the virtual platforms*". Some of the focus group members (8 out of 19) expected that this might cause a generation gap in the Metaverse environment, which can be extended to a social divide in the physical environment. Five other participants expressed the same concern, that younger generations are expected to be more able to develop knowledge transfer and communication interaction between human and non-human agents in virtual environments. The same challenge was raised in the focus group discussion, highlighting the need to accommodate the information processing properties and characteristics of Metaverse potential users born in the pre-digital age. "*As it requires high level expensive technologies, not everyone would afford to experience Metaverse, this mighty increase the socio-economic disparity, and enlarge the digital gap between developed and developing societies*", as expressed by a participant in the focus group.

4.1.4. Physical and Psychological Health Concerns

Some interviewees (9 out of 19) raised the concern of learners' health and safety. "*The disconnect from the real world could seriously impact learners' mental health*", as expressed by an e-learning expert. The VR expert identified some of the fatigue symptoms related to VR use, such as "*motion sickness, eye strain, headaches, nausea, and dizziness due to heavy VR headset*". The focus group participants recommended that headsets need to reduce in size and weight, to the point where they are easy and comfortable to wear for long periods of time, especially for young learners. The focus group also discussed the case of Zoom fatigue during the pandemic, including head and neck fatigue, as students spent too much time in virtual classes. It was discussed that an extended presence in the Metaverse could lead to addiction, social isolation, and antisocial behaviour. Young learners can be the targets of cyber-bullying and harassment. This finding matches with previous research suggesting that the Metaverse can have physical (obesity and cardiovascular diseases) and psychological effects (depression and anxiety), especially on young users who can use it to escape from the real world [6]. Addiction, social isolation, and abstinence from real, physical life, often combined with body neglect, are also reported as expected health concerns of extensive use of the Metaverse [10]. On the physical side, [6] predicts that future devices will be lighter and cater to more senses, including haptic gloves, and even full bodysuits for realistic touch sensation [6].

4.1.5. Governance

All the previously mentioned challenges raise the question of who is governing the Metaverse. Furthermore, "*The Metaverse will go beyond countries' boundaries and multiple regulations/traditions/laws might be relevant . . . .*", as expressed by an HCI expert. The focus group raised the issue of the Metaverse's governance to set policy for data security and miss-use, set privacy and confidentiality terms, ensure universal access, control physical and psychological health concerns, and handle other expected Metaverse challenges. The focus group participants reached a consensus that, namely in Meta-Learning, such a governing entity should ensure that accountabilities, rules of behaviour, codes of conduct, decision-making rights, and also incentives guiding behaviour are in place. "*Governance of the Metaverse is needed to maintain and update the whole platform ecosystem*", as written in a participant's essay. This finding is supported by [30], who highlighted that the Metaverse encounters governance challenges related to the applicability of the rule of law, national laws, policies, issues of consent and accountability, and private rulemaking.

4.2. Meta-Education Opportunities

4.2.1. Hands-On Training and Learning

All interviewees confirmed the possible positive impact of the Metaverse on e-learning, in terms of providing access to hands-on training using scenarios that could not be applied in the physical classrooms. "*Such as flight simulation training, surgical experiment, planet discovery, or simply chemistry experiment*", as mentioned by an educator interviewee. It was expressed that the Metaverse can go beyond the capabilities of the hybrid education, combining the physical classroom and e-learning platforms. Most interviewees (10 out of 19) cited that the Metaverse can deal with challenges of the current e-learning applications, such as learners' disengagement, by mirroring the learning face-to-face experience. "*In the Metaverse, learners would interact seamlessly with each other, with the educators, and the environment, while simulating the social and emotional communication, facial expressions, and body language of the physical world*", as cited by online learning expert interviewee. Metaverse can enable cost-effective and risk-free practice areas for trainees and students. Remote examination of patients in case of pandemic, fire protection exercises, are good examples. "*In Metaverse, professionals and learners, regardless of their physical actual location, can learn tasks without physical dangers, and can be trained on reactions to various dangerous situations, and practice unexpected situations*", as expressed by a focus group member.

The focus group participants reached consensus that the Metaverse could reshape a new era of e-learning, which they called *Meta-Education*. Compared to currently known online teaching tools such as Zoom, the ultimate Meta-Education can better simulate a physical classroom experience, allowing teachers to comprehend students' reactions and emotions, and hence adapt content based on individual reactions. The focus group recommended that Meta-Learning should be accompanied by a paradigm shift in course syllabus and content. "*Artificial Intelligence in the Meta-Learning can analyse students' body language and eye track, to conclude reactions to teaching content and/or approach .... Such conclusion would give teachers indications whether students are attentive, confused, or disengaged, based on which teaching activities can be adapted*", as expressed by a focus group member. The Meta-Learning would also handle the e-content and resources, allowing educators to focus on moderating discussion, motivating participation, and observing learners' reactions. Such a shift in the educator's role needs extensive training, as concluded by the focus group.

4.2.2. Game-Based Learning

The focus group discussed the capability of Meta-Education to allow hybrid formal and informal active learning experiences in online 3D virtual campuses and classrooms, where wider deployment of game-based learning methods is employed. It was suggested that the entire online syllabus can be gamified and implemented as multiuser online games in virtual worlds. "*Such game-based methods can foster learners' inclusion, initiative, and experimentation*", as elaborated by an interviewee. Thanks to the ability to capture 360-degree panoramic photos and volumetric spherical video, Meta-Learning can be especially useful in laboratory and surgery simulations, internal human body organs observation, STEM education, and field trips to a tropical forest or an underwater wreckage, as well as gamification of the syllabus. This recommendation for game-based Metaverse learning was also proposed by [31].

4.2.3. Collaboration in Creating Knowledge

Some of the interviewee (9 out of 19) highlighted the fact that Meta-Learning can open up new possibilities for collaborative learning, enabling teamwork of learners from different institutions world-wide, unbounded by geographical restrictions. Learners with diverse and collective skills can share experience and collaborate to solve challenging problems, by cooperatively learning and creating knowledge together, as discussed in the focus group. Such universal collaboration might need a built-in translation feature in a Meta-Learning platform, as suggested by an interface design interviewee. According to [3], such collaborative creation of knowledge can become a democratising factor in education.

5. Conclusions and Contributions

The results of the current research suggested that the Metaverse will have a revelational impact on the future of electronic and hybrid learning and training. As remote and virtual laboratories are gaining ground, a 3D virtual environment, where learners are equipped with needed information and resources, can make the learning process much more efficient. Previous research, prior to the Metaverse, estimated that future technologies can provide asynchronous 3D Virtual Reality training on machines and equipment that are difficult and expensive to obtain in physical reality [32]. Other research [33] suggested that a virtual learning environment with 3D animated contents would encourage inventive thinking and developing learners' creativity and innovative ideas in some areas. Furthermore, it was suggested that content learned in the Virtual Reality environment is stored more deeply in the human memory, hence resulting in a more efficient retrieval and learning process [34]. In that sense, the Metaverse can revolutionise education, being a suitable platform to provide access to a quality, cost-effective, more efficient retrieval, and inventive thinking-based learning experience. The current research highlights some Meta-Learning opportunities as being game-based and in a collaborative knowledge creation environment, especially in learning and hands-on training contexts.

The current research also highlights some Meta-Learning current and future challenges: In Metaverse learning platforms, learners' interaction is with an entire technological ecosystem featuring increased interactivity in the continuum between the physical and the digital. A main challenge would be to Challenge#1: Design an implicit three-dimensional interaction, within learners, between learner(s) and educator(s), and between both parties and the digital learning content. Recommendation#1: The design needs to be simple and comprehensive to avoid learners' cognitive overload. It also to be consistent with the real world, in order to minimise the uneasiness that could be caused during switching between two realities.

Being built on many layers of advanced technologies, Challenge#2: Potential Cybersecurity Vulnerabilities are expected in the Metaverse, with a contradicting concept of openness versus privacy. Recommendation#2: Security awareness should be raised within learners and institutions, while the Metaverse should account for the privacy of learners' data, with a clear consideration of data ownership. Sensitive data should be encrypted and privacy strategies for personal information collected by Metaverse platform suppliers should be established.

Challenge#3: With its expected technological complexity, Accessibility of the Metaverse could be a question mark for technologically developing societies and for non-tech-savvy users. This might cause a socio-economic disparity, widen the generation gap between users, and enlarge the digital gap between developed and developing societies. Recommendation#3: Service providers should be targeting a cost-effective access to Metaverse education. It should also be adaptive to various users' capabilities and preferences with comprehensive route search, with the possibility to enhance the user experience through exercises, training, and orientation.

Challenge#4: Health Concerns are suggested to be associated with extensive use of the Metaverse: on the physical (head and neck fatigue, eye strain, headaches, nausea) and psychological sides (addiction, social isolation, and antisocial behaviour), with young learners potentially being the targets of cyber-bullying and harassment. Recommendation#4: Long-term user experience testing is crucial to track the various possible harms. Headsets needs to be smaller, lighter, and more wearable, especially for young learners.

Challenge#5: Governance is needed, especially in Meta-Learning, as it will go beyond institutions and countries' boundaries and multiple regulations might be relevant. Recommendation#5: A governing body would ensure rules of behaviour, code of conduct, set a policy for data security, and set privacy and confidentiality terms.

Research on Metaverse-based learning Human–Computer Interaction, such as the current research, can raise the level of utilisation, development, and support of human cognitive abilities of the Metaverse, leading to more innovative ways of knowledge acquisition

adaptive to the abilities of the individual. With the expected continuous development of Metaverse technology, more opportunities could evolve; meanwhile, such a development could only be effective if the challenges are well known. The results of this research could be considered as a small step towards an effective Metaverse development.

6. Limitations and Future Work

Given the topic's newness, participants of the current research could have conflicting opinions on the Metaverse concept, as it is constantly changing due to its innovation and could be considered an umbrella term for a collection of virtual words. Additionally, there is a severe shortage in the literature relating to Metaverse-based learning platforms and its HCI aspects, hence the results of this research were not discussed thoroughly in comparison with previous findings. Future work can involve user testing with real devices on a Metaverse-based learning/training platform, with such usability testing fundamentally important to capture a more authentic understanding on how users are perceiving and using the platform. Another limitation of this study is the sample profile regarding age, as participants are of a relatively young age. As users born in the digital age are expected to be more able to develop knowledge transfer and communication interaction between human and non-human agents in virtual environments, future work concerned about universal access of Metaverse-based learning needs to address information processing properties and the characteristics of learners born in the pre-digital age, in the Metaverse context.

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