# Sustainability and Metaverse in Education and Training: Barriers, Opportunities and Environmental Impact

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***Abstract*— The proliferation of training experiences and experiments with the metaverse testifies the desire to test new instructional models to increase participant engagement, but also foster situated learning experiences to increase training effectiveness and learning outcomes. However, the creation of training paths in the metaverse is supported by an experimental approach, but also accompanied by curiosity and expectations, as well as by emerging questions about how to combine the opportunities of a new training technology with its adoption problems. In the definitions and experiences, it seems to be a lack of a real educational vision for correctly using this opportunity. In this paper, which is an initial approach to the problem of choosing a new technology, we want to examine the impact both in terms of training and on the environmental dimension, which is a generally underestimated topic in edtech (educational technology) choices.**

***Keywords-metaverse; instructional design; sustainability.***

## I. INTRODUCTION

Metaverse is one of current applications that is considered most interesting in edtech landscape and cited in trends of education & training industry observers in recent years. Contextually, both corporate trials and academic studies have been conducted with the aim of demonstrating the usefulness and educational effectiveness of this technology. At the beginning of 2023, however, on the communicative level in industry trends, this topic is found with less centrality in favor of the contamination of methods for a truly individualized (user-oriented) learning.

Since its first definition, Metaverse is considered "*a decentralized network of computer-generated worlds, where users feel a genuine sense of being in these spaces for work, leisure and learning*" [22]. Particularly in recent years with the increasing development of technology capacity, also studies and experimentations increased in a practical use of possible applications of the metaverse in education and training. Authors who are in favor of using metaverse, identify great educational opportunities in creating a virtual and interactive equivalent to the physical world through exploration on Extended Reality (XR) platforms. This definition embraces immersive technologies as Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality (VR). So, there is a spectrum of virtuality, which are already transforming society in technological, industrial, and legal worlds [19].

The ability to act in a virtual and interconnected world to search information, communicate and explore an augmented reality led to imagining a future in which only a reduced and blurred boundary will exist between the virtual and real worlds. As Ng [17] points out, the use of the term metaverse has greatly increased after 2020 to identify technologies that were being discussed even before that year:

- Since the 2000s to the mid-2010s, researchers used the term metaverse to refer to virtual environments such as gamification and avatar-based learning to indicate platforms e.g. Second Life, Digital Virtual World [1] [21]. They emphasized the possibility in building immersive, three-dimensional, multi-user experiences to create authentic learning environments to enrich the educational experience.
- After the mid-2010s, even with a significant improvement of technologies, the definition of metaverse in education didn't change so much, i.e., a 3d simulation environment that encourages communication (with simulated objects/avatars and with other participants), interaction and collaboration by providing active agents to build the learning process was identified with this term [2].
- Since 2020, the term Metaverse has returned to common interest, however, not changing its intrinsic meaning in the educational field. Diaz et al. [5] identify with this term virtual spaces that recreate the real world, learning processes and experiences, through avatars used to interact with other users as in real life. Kye et al. [13] describe the metaverse as a space for a new form of social communication with greater freedom for users to share ideas, thoughts and digital artifacts. Reyes' [20] definition fully identifies the foundational assets of the metaverse:
    - *Interactivity* that facilitates the construction of autonomous and collaborative learning scenarios;
    - *Corporeality* that allows people to represent themselves through avatars;
    - *Persistence* that enables the construction of a virtual world that mimics the real world and keeps people interconnected over time.

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In distance learning, this blended approach allows new formal and informal learning modalities emerge, in which physical presence is not a mandatory requirement of the educational experience [13] anymore. Instead, the use of immersive technologies enables educational experiences and allows a deeper and longer learning [16]. Girvan [9] argues that this new learning formula can ensure a democratization of education, allowing access even for people from disadvantaged areas.

We summarize below some emerging indications from the literature in comparison with our own critical reading.

TABLE 1 . OPPORTUNITÀ SEGNALATE IN LETTERATURA E VALUTAZIONE DELLE POSSIBILI ALTERNATIVE

| Opportunity statements | Questions |
|---|---|
| Metaverse provides more interactive education without compromising the classroom experience [12]. | Does interactivity depend on used method or technology? |
| Applications of the metaverse can provide a more accessible way for communication, improving educational quality [4]. | Can training effectiveness also be pursued in other ways? |
| The teaching process can be managed independently from time and space with enriched teaching experiences. | Can other technologies equally enable the exploration of different worlds (at microscopic or macroscopic level) and eras, depending on the educational objectives? |
| Metaverse provides immersive, higher participation learning experiences and reducing isolation | But could it be also the other way around? Could it increase the risk of isolation? |
| Students can become knowledge creators. | Is content creation also possible with other technologies? |
| Educational resources will be plentiful and increasing | But what will be the necessary investments? |
| Online 3d metaverse campuses can realize rich, liquid, integrated learning environments and provide rich educational opportunities [3] | What will be the enrollment policies to ensure everyone's right to study? |

Possible drawbacks and problems to be addressed are also highlighted:

- Teachers need to learn new methods and acquire digital, design and instructional process management skills in the metaverse. Contact and relationship in presence are necessary in educational and training activities.
- Investments in technology and development of environments and contents with complex, high-quality graphics are required. There is still a low availability of catalogs with digital resources and metavers has high production costs and even access devices are expensive. Privacy and cybersecurity are issues related to the use of digital devices that collect and use data (including biometric data) that must be ensured under a regulatory and informational perspective toward the user. Also a part of little knowledge or confidence in technology and awareness of educational applications persists [16].
- Excessive cognitive load for Extended Reality (XR) experiences that provide many audio-visual stimuli to the user, so it is necessary to identify the correct methods to make this aspect become an advantage for effective learning and retention, rather than instead a barrier. This also requires defining time constraints for these experiences estimated at 10-15 minutes [19].
- The issue of accessibility is very complex under the perspective of used technologies. Increasingly, technologies must evolve to ensure full and equal inclusion and accessibility. [19].

Then there are emerging topics related to the use of technological environments such as [24] those related to Data Management, Digital Copyright, equity and sustainability of education, and the impact of algorithms in educational processes. There are, however, areas and purposes for which experts find the use of Extended Reality (XR) challenging and productive, including:

- increase participant motivation and interest: studies show an increase in self-efficacy through experiential training [14].
- build comprehensive learning environments in which the learner can develop learning through immersive technologies enriched by advanced computing (AI – Artificial Intelligence, data mining, etc.) by developing socialization, collaboration in learning environments and decentralization to increase learning opportunities and technologies [17].

In this scenario and with these available studies, a global consideration about impacts in learning and other impacts must be done. In Section 2 we discuss effective opportunities to implement metaverse solutions in education and training with honest remarks about possible problems and alternatives. In section 3 we provide a wider perspective on the use of technologies in an ESG framework.

## II. OPPORTUNITIES FOR TRAINING AND BARRIERS TO ADOPTION OF METAVERSE

Undoubtedly, metaverse appears to be a very interesting chance in the educational and training sector with experiencing worlds and eras other than reality, interacting in complex ways through avatars in contexts even very distant from personal environment, breaking down access boundaries and overcoming distance or language limits.

Metaverse could represent a great opportunity in all those training activities that are difficult to replicate or implying high risk, as for example, in the training of technicians operating in a semi-automated production process. Metaverse offers the possibility to engage in trials with equipment, processing times, and quality control procedures without incurring risks or injuries, even interacting with each other and/or with instructors in real time. Creating a safe and controlled training environment where users can practice and make mistakes without negative consequences is, in our opinion, one of the greatest potentials. In addition, learning can be adapted to users' background and prior skills or specific needs by overcoming barriers to access or habitual behaviors.

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It is important to remember that technology is a tool and not a miracle solution [19], that it can support learning processes particularly in so-called Dangerous, Impossible, Counterproductive, Expensive (DICE) situations, and yet it does not solve the problems of a poorly designed or managed training process. The application of metaverse technologies in training, therefore, requires extensive considerations on training objectives and models, user experience, and real training potential. As metaverse will grow, experiences and content will emerge, and even appropriate instructional solutions could be tested to ensure that the tool is not just another expensive and underutilized training application.

## III. TECHNOLOGY ENVIROMENTAL IMPACT CONCEPT

It is also important to consider the assessment of the environmental impact of technologies, a factor that is often overlooked when evaluating opportunities and innovations. It is true that calculating the real environmental impact is a huge, if not impossible, problem. It is in fact the sum of a complex series of types of pollution: gas emissions, water consumption, consumption of raw materials, deforestation, urban sprawl, human and animal exploitation, and so on. And this calculation becomes even more difficult for something that does not yet exist: the metaverse. The only certainty we have is that as the number of online events grows, so does the energy demand of the entire infrastructure. According to the Shift Project report [27], digital growth is unsustainable; in fact, the energy consumption of current digital activities is growing at 9% per year, and with the advent of the metaverse, this growth can only continue to grow exponentially. The metaverse will rely on an infrastructure based on cloud computing, blockchain, artificial intelligence and virtual reality. Let's try to analyze them one by one:

- **Cloud Computing**: cloud services are essential for virtual reality and the metaverse. According to a 2020 analysis by Lancaster University, a scenario in which 30% of gamers switch to cloud gaming will lead to a 30% increase in CO2 emissions by 2030 [28]. Not to be overlooked is the water consumption required by data centers. To get an idea, Google's data centers alone used about 16 billion liters last year, which is comparable to the water consumption of an Italian city with a population of about 185,000 [10] [6].
- **Blockchain**: bitcoins alone have a carbon footprint comparable to that of New Zealand, producing approximately 36.95 tones of CO2 per year [26]. The use of blockchain is probably the big change and the only real benefit, as the transparency of this technology would force companies to track, submit and manage their green policies [8]. Below are graphs about of the bitcoin network's CO2 emissions (Figure 1) and energy consumption over time (Figure 2) [27].


Figure 1. Estimated CO2 emission (MT) of the Bitcoin network

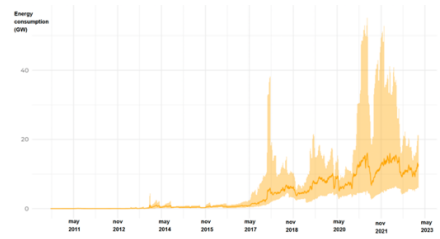


Figure 2. Daily energy consumption (GW) of the Bitcoin network

- **Artificial Intelligence**: according to Strubell et al [23], training a single neural network can generate up to 284 tones of carbon dioxide, which is more than five times the amount of CO2 emitted by an average car (Table 2). Further confirmation of the order of magnitude comes from Patterson [18], who calculates the emissions for training the model behind OpenAI's famous ChatGPT, GPT-3: 500 tones of CO2.

TABLE 2 . CONFRONTO CONSUMI RISPETTO ALL'ADDESTRAMENTO DI UN MODELLO GPU [19]

| **Consumption** | **CO2 (Kg)** |
|---|---|
| Air flight, 1 passenger, NY ⇔ SF | 900 |
| Human life, 1 year | 5000 |
| Life of an American, 1 year | 16400 |
| Car, whole life | 57153 |
| **Training a model (GPU)** | |
| NLP pipeline | 18 |
| with tuning and experimentation | 35592 |
| Transformer (large) | 87 |
| with neural architecture search | 284019 |

Considering these data, it is possible to conclude that a public access network that connects various devices or terminals throughout, extending the real world, based on the mentioned technologies, can only increase the use of all technologies and consequently also the ecological impact.

Finally, we would like to quote Hwang's definition of the metaverse [11]: *"The metaverse has been recognized as being the next generation of social connection. It refers to a created world, in which people can "live" under the rules defined by the creator. A metaverse could be fully or partially virtual; for example, it could be a fully virtual world like a virtual reality (VR) system, or a partially virtual world like the use of augmented realty (AR) in real-world contexts. In the metaverse space, people can engage in social activities such as discussing an issue, collaborating on a project, playing*

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*games, and learning from experiencing or solving some problems."*

But are we sure that all these benefits are not already realized with "the current Internet"?

## IV. CONCLUSION

Despite the enthusiasm and clear benefits of using metaverse, we must always maintain a global perspective and consider all the issues associated with the use of technology. Data use, training ethics and environmental impact are just some of the issues that should not be underestimated in the conscious adoption of these innovations for training activities.

Increasingly, companies and training institutions need to understand the global impact of their methodological and technological choices in the virtual world have on the real world. This paper represents the beginning of a corporate consideration of how facing emerging technologies. The next steps of this research will aim to measure the carbon footprint of all digital training products and include it in its quality assurance programs and ESG (Enviromental Social Governance) policy.

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