TOWARD ETHICAL AND SOCIALLY GROUNDED DIGITAL SUSTAINABILITY: HUMAN-CENTERED TECHNOLOGY AND THE METAVERSE IN INDUSTRY 5.0

DOI: 10.26341/issn.2241-4010-2026-7a-1-L02179

Kalemis Alexandros
PhD(c) Urban & Regional Planning, National Technical University of Athens School of Architecture, Greece
akalemis@mail.ntua.gr

Abstract
This paper explores the role of Industry 5.0 as a paradigm shift that transcends the boundaries of Industry 4.0, proposing a human-centered and ethically oriented approach to technological design. At the core of this study lies the metaverse, which emerges not only as an innovative technological environment but also as a cultural and social framework with the potential to foster digital citizenship, experiential education, and participatory design. The analysis is grounded in a critical review of international literature and a systematic thematic synthesis that draws on insights from the fields of the ethics of technology, science-society studies, and digital sustainability.

Specifically, the paper examines the philosophical and political foundations of Industry 5.0, emphasizing resilience, collaborative intelligence, and fairness in access to digital infrastructures. It further analyzes metaverse applications in areas such as education, environmental management, healthcare, and social inclusion, while also identifying risks related to digital exclusion, algorithmic control, and environmental burdens. Special attention is given to the importance of transparency and accountability in digital design, as well as to the need for shaping frameworks of technological citizenship that advance democratic participation and ethical responsibility.

The study argues that digital sustainability cannot be reduced to technical approaches of energy efficiency, but requires a holistic perspective that integrates social, cultural, and ethical dimensions. The proposed theoretical and practical framework demonstrates how the metaverse can serve as a field for practicing new forms of technological humanism, strengthening collective resilience and institutional transparency. From this standpoint, Industry 5.0 is revealed not merely as a technological evolution but as a profound cultural and social shift that redefines the human-technology relationship toward a more just, inclusive, and sustainable future.

Key words: *Industry 5.0, metaverse, digital sustainability, technology ethics, social justice, digital citizenship, technological humanism*

INTRODUCTION

The trajectory of industrial and technological development over recent decades has been marked by the rapid digitalization of production, the convergence of the physical and digital worlds, and the emergence of a technological ecosystem that redefines the relationship between human beings, machines, and society. The Industry 4.0 paradigm, focused on automation, artificial intelligence, and networks of cyber-physical systems, has delivered significant achievements in efficiency and innovation; however, it has simultaneously

exposed profound ethical, social, and environmental imbalances (Van de Poel & Royakkers, 2023).

Industry 5.0, as defined by the European Commission and analyzed in contemporary literature, does not constitute a mere technological continuation but rather a paradigmatic shift from technocentrism toward human-centered, sustainable, and socially responsible innovation (Bielicki, 2024; Mohammed et al, 2026). It emphasizes resilience, collaborative intelligence, and equitable access to digital infrastructures—elements that bring the value-laden dimension of technology back to the forefront and reframe engineering practice as an act of social responsibility (Werthner et al., 2024).

Within this context, the metaverse emerges as a landmark domain of the new industrial era. It is not merely a collection of virtual or augmented worlds, but a comprehensive socio-technological sphere in which humans participate simultaneously as users, creators, and citizens (Bibri, 2022; Dwivedi et al., 2022). Virtual and augmented reality platforms, as extensions of collective experience, offer new modes of communication, education, participation, and design, redefining concepts such as digital identity, community, and democratic participation (Lee et al., 2024).

However, this technological prospect is accompanied by a wide range of ethical and social challenges. Dependence on algorithmic systems and the concentration of data within global digital ecosystems generate new forms of surveillance, exclusion, and inequality (Robinson et al., 2020; Graham & Wood, 2003). The question of digital autonomy and personal identity in cyberspace (Elliott, 2015) thus becomes a central concern of a technological ethics grounded in transparency, accountability, and empathy.

The present study seeks to illuminate this cultural turn toward ethically grounded digital sustainability by linking the concepts of technological human-centeredness, social justice, and digital citizenship. It examines the role of the metaverse both as a space for social experimentation and democratic education, and as a domain of risk associated with the hyper-mediation of experience and the governance of information.

The core hypothesis of this paper is that digital sustainability cannot be confined to technical approaches such as energy efficiency or technological upgrading, but instead requires a holistic, socially grounded, and human-centered perspective. From this viewpoint, Industry 5.0 constitutes not merely a technological innovation, but a cultural project that reshapes the relationship between humans and technology toward a just, participatory, and transparent future (Braidotti, 2013).

Criterion	Industry 4.0	Industry 5.0	Interpretive Commentary
Central Objective	Automation, efficiency	Human-centered and socially responsible innovation	Shift from technocracy to human–technology collaboration
Role of Technology	Mechanistic, instrumental	Collaborative, supportive	Technology becomes a partner rather than a replacement for humans
Conception of the Human	User / producer	Creator, citizen, co-designer	Humanistic re-signification of technology
Ethical Foundation	Neutral	Normative, value-based (transparency, inclusion)	Ethics of technological responsibility
Social Perspective	Competition, efficiency	Cooperation, collective intelligence	Industry 5.0 as social innovation

Table 1: Industry 4.0 vs Industry 5.0 in a Comparative Perspective

AIMS, RESEARCH QUESTIONS, AND STRUCTURE OF THE PAPER

The present paper aims to investigate the ethical, social, and cultural dimensions of the technological transition toward Industry 5.0, with particular emphasis on how the development of the metaverse can function as a laboratory for digital sustainability, participatory innovation, and technological humanism.

In contrast to earlier phases of industrialization, where humans were primarily regarded as agents required to adapt to machines, Industry 5.0 seeks to restore a symmetrical relationship between humans and technology by introducing new forms of co-creation, empathy, and ethical responsibility (Salimova et al., 2020; Van de Poel & Royakkers, 2023). Within this framework, the metaverse is not treated merely as a technological environment, but as a cultural and social construct capable of significantly shaping the notions of digital identity, citizenship, and sustainable development (Doueihi, 2014).

Within this framework, the present study seeks to elucidate the philosophical and ethical foundations of Industry 5.0, focusing on concepts such as resilience, collaborative intelligence, and social justice in relation to access to digital infrastructures. At the same time, it examines the metaverse as a complex socio-technological environment capable of fostering forms of experiential learning, social inclusion, and environmental awareness, functioning as a space for experimentation and critical reflection on sustainable digital practices. Particular emphasis is placed on the transformations of digital identity and subjectivity in cyberspace, as well as on the risks arising from mechanisms of algorithmic control and phenomena of digital exclusion. Finally, the study proposes an ethically and socially grounded framework of digital sustainability that links transparency, accountability, and democratic participation to the design and implementation of technological systems.

The study is organized around **four central research questions**:

1. How is the concept of technological ethics redefined within the framework of Industry 5.0, and what is its contribution to the development of socially responsible technologies?
2. In what ways can the metaverse function as a field for practicing technological humanism, enhancing participation, creativity, and sustainability?
3. What new forms of digital identity and subjectivity emerge in cyberspace, and what ethical and political dilemmas do they raise for the notion of the "person" in the digital age?
4. How can digital sustainability be defined as a synthesis of technological, social, and ethical parameters that contribute to democratic and sustainable development?

In order to address the aforementioned research questions, the paper is organized into seven interrelated sections. It begins with an introduction that outlines the theoretical and historical context of the transition from Industry 4.0 to Industry 5.0 and clearly defines the central research problem. The second section develops the theoretical framework, examining the philosophy and ethics of technology, its intersections with posthumanist thought, and the emergence of digital humanism as a normative paradigm. The analysis then turns to the metaverse as a socio-technological environment, exploring its potential as a space of co-creation, education, and social interaction, while critically assessing the opportunities and risks it entails.

Subsequently, the paper investigates the construction of digital identity and subjectivity in cyberspace, with particular attention to practices of surveillance and the ethical implications of self-representation. The discussion then expands to the concept of digital citizenship, analyzing its relationship to transparency, trust, and participatory decision-making processes. This is followed by a section presenting concrete applications and case examples that illustrate the implementation of Industry 5.0 principles in fields such as education,

environmental policy, and social innovation. Finally, the concluding section synthesizes the main findings and advances a framework of ethical sustainability intended to inform and guide future technological transitions.

THEORETICAL FRAMEWORK: ETHICS, HUMANISM, AND DIGITAL SUSTAINABILITY

The discussion surrounding Industry 5.0 brings back to the forefront an enduring yet ever-relevant question: what is the place of the human being in technological progress? In contrast to Industry 4.0, which emphasized efficiency, automation, and the integration of cyber-physical systems, Industry 5.0 seeks a new equilibrium between technological rationality and ethical reasoning. The concept of human-centered design constitutes a cornerstone of this new era, as it reframes technological development as a process of human empowerment rather than human replacement. Werthner et al. (2024), within the framework of Digital Humanism, emphasize that technology is not value-neutral; it embodies cultural assumptions, institutional structures, and forms of power. From this perspective, Industry 5.0 must recognize technology as a carrier of social relations, rather than merely as a technical instrument.

The ethics of technology has evolved into a distinct field of inquiry that examines how technical decisions embed values, preferences, and forms of social power (Van de Poel & Royakkers, 2023). The transition toward Industry 5.0 requires an ethics-by-design approach; a methodology in which principles such as transparency, accountability, and justice are integrated from the earliest stages of technological design. In the same vein, Robison (2024) argues that engineering activity is inherently normative: every design choice constitutes a decision about who benefits and who is excluded. Consequently, engineering ethics becomes a foundational element in the construction of responsible technological systems capable of sustaining social trust and ensuring equitable access to digital goods. As Bielicki (2024) notes, the human-centered transition of Industry 5.0 does not merely presuppose respect for the user, but rather the creation of co-creation frameworks, in which humans and machines collaborate toward shared objectives. This collaborative intelligence establishes a new ethical ecology of technology, wherein human judgment remains the decisive regulator of system autonomy.

Posthumanism and Digital Humanism

The philosophical foundations of Industry 5.0 draw upon the dialogue between posthumanism and digital humanism. Rosi Braidotti (2013) conceptualizes posthumanism as a theoretical current that deconstructs the anthropocentrism of modernity and recognizes the entanglement of the human, the artificial, and the natural. From this perspective, the human ceases to function as the measure of all things and instead becomes a relational node within a network of material, digital, and biological processes. Digital humanism reasserts the critical responsibility of the human as creator and steward of technology. It advocates a form of technological humanism that combines innovation with social sensitivity, where progress is measured not solely by productivity indicators, but also by indices of well-being, transparency, and justice.

Together, these theoretical approaches allow Industry 5.0 to be understood as a cultural shift, rather than merely a technological evolution: an effort to reconnect the technical with the ethical, and the digital with the human.

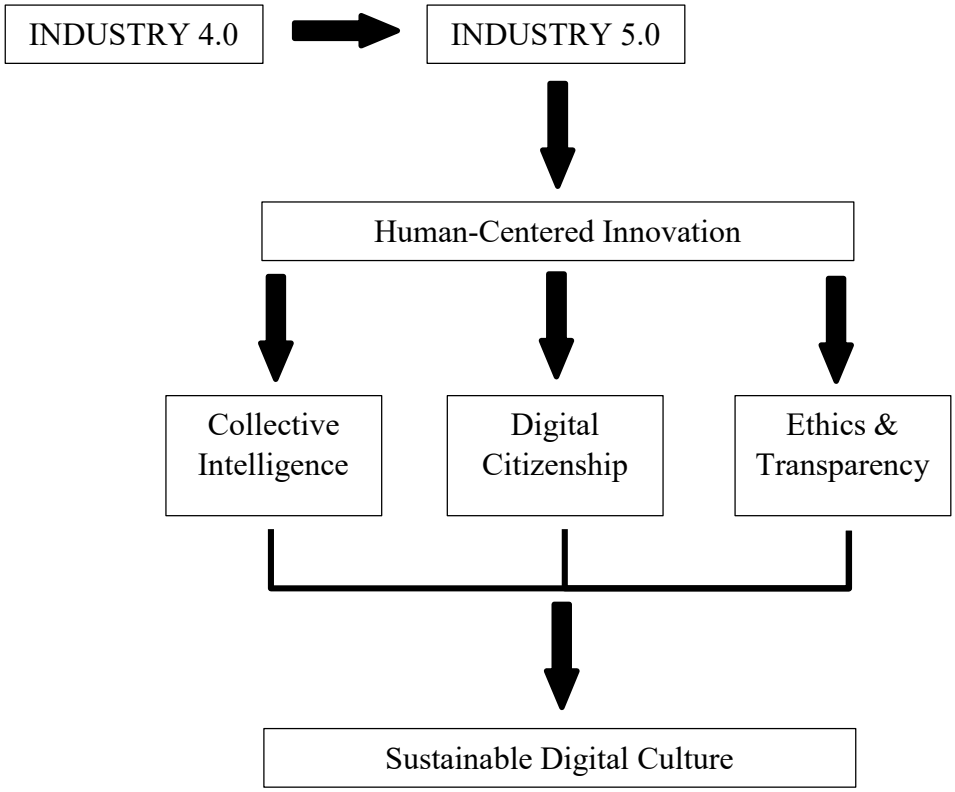

Figure 1: Conceptual Framework of Industry 5.0

From Ecological to Digital Sustainability

In the contemporary era, the concept of sustainability extends beyond the environmental domain to encompass social, cultural, and digital dimensions of development. Digital sustainability refers to the capacity of technological systems to persist, evolve, and contribute to social cohesion without generating new forms of inequality or environmental burden.

Within this context, Allam et al. (2022) proposes viewing the metaverse as an alternative form of a "smart city," where digital participation and collective content creation can strengthen sustainable urban governance. Similarly, Bouzguenda et al. (2019) emphasize that active citizen participation in digital environments can function as a mechanism of social sustainability.

The transition from "green" to digital ecology, therefore, presupposes a new form of responsibility; an ethics of digital culture in which data consumption, resource management, and collective knowledge are governed by principles of transparency, justice, and equal access (Morton, 2013; Crist, 2019).

THE METAVERSE AS A SOCIO-TECHNOLOGICAL FIELD

In recent years, the concept of the metaverse has emerged as a multidimensional space that integrates immersive technologies, digital identities, innovative forms of collaboration, and new economies of content creation. Beyond its popular interpretation as a "virtual world," the metaverse is increasingly defined as an ecosystem of interactions that shapes social practices, cultural representations, and new forms of digital life (Lee et al., 2024).

Within the framework of Industry 5.0, the metaverse does not merely constitute a technological innovation, but rather a domain for the practical application of human-centered and collaborative intelligence. It incorporates principles of participatory creation and distributed experience, transforming users from passive recipients into active co-creators of digital and social environments (Chung, 2025).

Definition and Evolutionary Dynamics of the Metaverse

The term metaverse derives from the combination of the words meta (beyond) and universe, symbolizing a form of hyper-reality in which the physical and digital coexist within a continuous spectrum through technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and blockchain (Lee et al., 2024). According to Dwivedi et al. (2022), the metaverse represents a new phase of digital transformation in which the internet experience ceases to be two-dimensional and becomes experiential and socially participatory. In this sense, individuals do not merely "navigate" the internet; they inhabit it. This dynamic positions the metaverse as a potential implementation space for Industry 5.0, where technology serves human creativity, learning, and social coexistence. The convergence of the metaverse and Industry 5.0 may give rise to forms of collective intelligence that combine artificial and human systems for socially beneficial purposes.

The Metaverse as a Social and Cultural Environment

Beyond its technical definition, the metaverse constitutes a cultural rupture. It is a space in which users construct identities, participate in communities, and develop new forms of cultural expression (Kalemis, 2025a). Its social dimension rests on the premise that virtual worlds are not mere "replicas" of reality, but arenas for the production of social relations, values, and meanings (Johnson, 2023). Arghashi (2024) emphasizes that the metaverse offers users the experience of fluid and adaptable identity, allowing subjects to reconstruct themselves through aesthetic and social practices. This fluidity resonates with early theories of the *cyberself* developed in the 1990s (Jones, 1998), now reinterpreted in light of immersive technologies. At the same time, community within the metaverse acquires cultural significance. Virtual user groups give rise to forms of collective creation, dialogue, and social learning reminiscent of *communities of practice*. These emerging forms of digital sociality can function as laboratories for democratic education, intercultural coexistence, and the ethics of collaboration (Frau-Meigs et al., 2021).

Ethical and Social Challenges of the Metaverse

Despite its potential and advantages, the metaverse generates a set of ethical and social challenges related to privacy, transparency, environmental sustainability, and users' psychosocial well-being.

1. Privacy and data control: Behavioral, movement, and biometric data collected within immersive virtual environments create unprecedented forms of surveillance. Skinner-Kravchenko et al. (2025) warn that the "liminal experiences" of digital immersion may lead to violations of personal space that exceed traditional conceptions of privacy.
2. Algorithmic bias and lack of transparency: Yeung and Lodge (2024) describe the phenomenon of *algorithmic regulation*, whereby digital algorithms shape behavioral norms and acquire regulatory power without adequate social oversight.
3. Environmental footprint: Despite its "digital" nature, the metaverse requires substantial energy consumption. Triantafyllidou and Zabaniotou (2021) argue that a "green" digital transition must account for the environmental footprint of virtual infrastructures.

4. Digital exclusion and social inequality: Agarwal and Alathur (2023) highlight the risk of creating a new "post-digital elite"; those with access to immersive technologies, while others remain excluded from the virtual ecosystem.

These challenges underscore the need for an ethical architecture of the metaverse—an approach in which technological design is guided by social responsibility rather than innovation alone.

Summary Perspective

From the above, it can be concluded that the metaverse can be understood not only as a technological innovation, but as a socio-cultural ecosystem that embodies the defining characteristics of Industry 5.0: collaborative intelligence, human-centered ethics, and participatory knowledge creation.

The essence of this approach is captured in the triadic formulation:

$$\text{Metaverse} = \text{Technology} \times \text{Culture} \times \text{Ethics}$$

Its success depends not on the sophistication of its algorithms, but on its capacity to cultivate relationships, trust, and collective identity within digital environments.

DIGITAL IDENTITY AND SUBJECTIVITY IN CYBERSPACE

The development of the metaverse and immersive environments signals a radical transformation in the concept of identity. Within the framework of Industry 5.0, technological progress no longer concerns only the optimization of machines, but also the reconfiguration of the human subject itself. Identity ceases to be static or unitary and becomes fluid, multilayered, and continuously negotiated within the networks of interaction that define cyberspace (Elliott, 2015).

The transition from the physical to the digital body, from the "person" to the "avatar", introduces a new form of technological subjectivity in which the boundaries between experience, representation, and self-determination become porous. This transition is not merely technological but ontological, as it reopens the fundamental question: *what does it mean to be human in environments of digital coexistence?*

The Construction of the Self in Digital Environments

According to Milad Doueihi (2014), identity in cyberspace is not a simple transfer of physical personality but the outcome of an ongoing negotiation between the subject and their technological traces. The digital self does not preexist technology; rather, it is continuously shaped through interactions, connections, and representations generated online. This constantly evolving data-self is characterized by the diffusion and reproducibility of digital information. Identity no longer belongs exclusively to the individual but is shared with the digital environments that host it, environments that often determine how individuals perceive themselves (Van Dijck, 2013; Ernst, 2013). Elliott (2015) adds that in the postmodern condition, identity is experienced as relation rather than essence: it emerges through continuous communicative interaction and social mirroring. In this sense, the metaverse functions as a new psychosocial laboratory in which the experience of the self becomes experimental and multiple.

The use of avatars in virtual environments operates as an embodiment of the digital person. According to Arghashi (2024), the interaction between realism and awe in immersive environments produces a form of hybrid consciousness, in which users simultaneously experience the "self" and the "other" through technology. This dual experience recalls the

ancient Greek concept of *prosōpon* (mask), a form of social and theatrical representation. Just as the theatrical mask expresses a role without exhausting the actor's identity, the avatar in the metaverse expresses the self without fully defining it. This interpretation is reinforced by Braidotti's (2013) work, which argues that digital subjectivity is not merely technologically enhanced humanism, but a posthuman experience, in which identity is produced through flows of information and relations.

The emerging forms of identity in cyberspace are deeply embedded in political and economic structures. Control over personal data, algorithmic recommendation systems, and the commodification of attention constitute new fields of digital power. Aradau and Blanke (2019) introduce the concept of algorithmic reason, suggesting that algorithms function as a new mode of governing the self: they predict, categorize, and influence user behavior. Huberman (2024) characterizes this phenomenon as the "spirit of digital capitalism," in which identity becomes an economic resource. From a legal perspective, Albers and Sarlet (2024) argue that the protection of personality and privacy in cyberspace must rest not only on regulatory measures, but also on the recognition of the person as a subject of information. Digital autonomy therefore presupposes the safeguarding of each individual's capacity to control their representation, data, and data usage.

Identity, Trust, and Social Inclusion

Digital identity concerns not only individual self-perception but also social belonging. Sebastião (2015) introduces the concept of *Digitania*© to describe the "demystification of digital citizenship": the need to understand technology not as a substitute for society, but as a reflective tool for examining the values and relationships that constitute community.

Within this framework, digital identity acquires an ethical dimension, encompassing trust, recognition, and responsibility toward others. Tsilis (2016), drawing on the sociology of the Greek cyberspace, emphasizes that online identities are not "virtual" in the sense of being false; they represent new forms of social existence that coexist with physical ones.

Industry 5.0 can play a decisive role in shaping frameworks of technological citizenship, in which digital identity is recognized not as a commodified profile, but as a right to participation and expression within a just digital public sphere.

The examination of digital identity leads to two overarching conclusions:

1. Technology reshapes forms of subjectivity, generating new domains of experience, creativity, and sociality.
2. The governance of this identity requires new forms of ethical and political accountability, ensuring that digital existence remains compatible with the principles of human dignity, freedom, and self-determination.

From this perspective, Industry 5.0 emerges as the first technological paradigm to integrate identity as an ethical and political parameter in system design. The challenge is no longer the technical capacity for immersion, but the democratic consciousness of digital presence.

DIGITAL CITIZENSHIP AND DEMOCRATIC PARTICIPATION IN INDUSTRY 5.0

The transition to Industry 5.0 redefines not only the relationship between humans and technology, but also the nature of citizenship itself. In an era where political, social, and cultural interactions are increasingly mediated by digital infrastructures, citizenship can no longer be understood solely within the boundaries of the nation-state. Instead, it acquires a digital dimension, encompassing participation, responsibility, and agency within networked public spheres (UNESCO, 2022).

Digital citizenship within Industry 5.0 is not limited to technical competence or access to platforms. It entails a normative framework grounded in ethical participation, critical awareness, and co-responsibility for the technological systems that shape collective life. As such, democratic participation becomes inseparable from technological design and governance.

Traditional conceptions of citizenship emphasized legal status, rights, and obligations within a defined political community. In contrast, digital citizenship expands these notions to include participation in digital decision-making processes, data governance, and algorithmic transparency (Isin & Ruppert, 2020).

Frau-Meigs et al. (2021) argue that digital citizenship requires the cultivation of *civic online reasoning*, enabling individuals to critically evaluate information, engage in deliberation, and resist manipulation in digital environments. Polizzi (2020) similarly emphasizes the importance of media and information literacy as a foundation for democratic resilience in the digital age. Within Industry 5.0, citizenship thus becomes an active practice rather than a passive status, one that depends on the capacity of individuals to shape, contest, and co-design the technological systems they inhabit.

Participation, Co-Creation, and Collective Intelligence

A defining feature of Industry 5.0 is the emphasis on participatory innovation. Digital platforms, immersive environments, and the metaverse enable new forms of co-creation in which citizens are not merely users of technology but contributors to its development and governance. Tapias et al. (2024) highlight the role of design thinking and collaborative platforms in fostering collective intelligence. These processes allow diverse actors—citizens, engineers, policymakers, and educators—to collaboratively address complex social challenges, from environmental sustainability to urban planning.

Such participatory frameworks challenge technocratic models of governance by reintroducing deliberation, plurality, and shared responsibility into technological decision-making. In this sense, Industry 5.0 aligns technological innovation with democratic values.

Risks to Democratic Participation in Digital Environments

Despite its emancipatory potential, digital participation also entails significant risks. Algorithmic curation, misinformation, and platform monopolies can distort public discourse and undermine democratic deliberation (Skinner-Thompson, 2024). The concentration of power within large digital corporations raises concerns about platform governance and the privatization of public space. As Katzenbach and Ulbricht (2019) argue, algorithmic systems increasingly act as political actors, shaping visibility, relevance, and participation without democratic accountability.

Moreover, digital divides, whether based on access, skills, or cultural capital, risk excluding significant segments of the population from meaningful participation. Without targeted policies of inclusion, digital citizenship may reproduce or even exacerbate existing social inequalities. In response to these challenges, Industry 5.0 calls for a shift toward democratic governance of technology, integrating ethical principles, legal safeguards, and participatory mechanisms into system design. Key elements of such governance include transparency in algorithmic decision-making, protection of personal data and digital identity, inclusive access to digital infrastructures, and institutional frameworks for citizen participation in technological policy. In this view, digital citizenship is not an auxiliary feature of technological progress, but its ethical foundation.

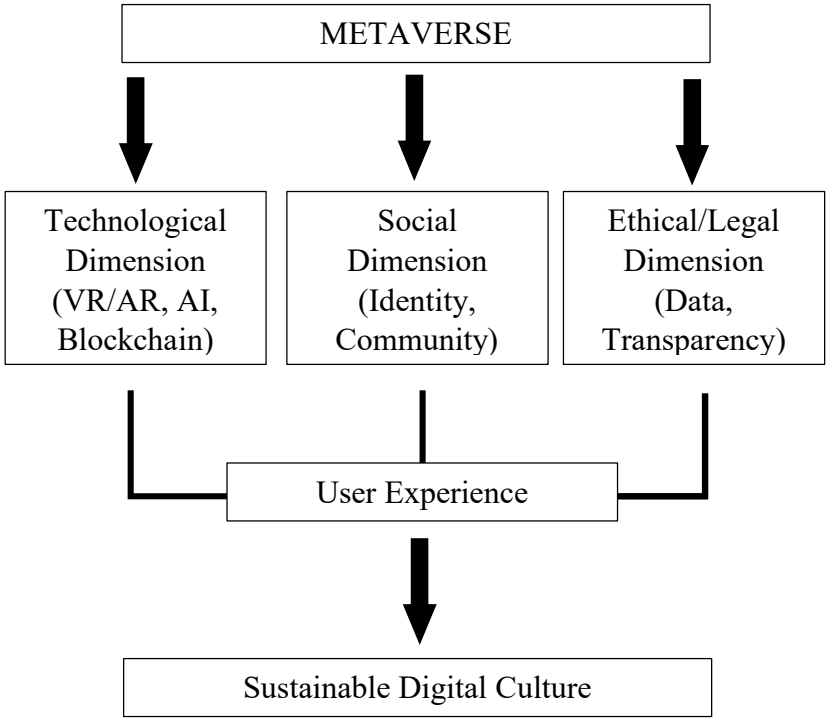

Figure 2: The Metaverse as a Hub of Coherence between Technology, Culture, and Ethics

APPLICATIONS AND CASE EXAMPLES: INDUSTRY 5.0 IN PRACTICE

The principles of Industry 5.0—human-centeredness, ethical responsibility, and digital sustainability—are not merely theoretical constructs but are increasingly reflected in applied practices across education, environmental governance, urban planning, and social innovation. This section presents indicative applications and case examples that demonstrate how the metaverse and related digital technologies can be deployed in socially meaningful and democratically grounded ways. Rather than offering an exhaustive empirical survey, the cases discussed below function as illustrative paradigms, highlighting the transformative potential of Industry 5.0 when technological development is aligned with ethical and social objectives.

Education and Experiential Learning in the Metaverse

One of the most promising application domains of the metaverse within Industry 5.0 is education. Immersive learning environments enable experiential, participatory, and collaborative forms of knowledge acquisition that extend beyond traditional classroom models (Kalemis, 2025b). Virtual campuses, laboratories, and simulations allow learners to engage actively with complex phenomena, ranging from environmental systems to historical reconstructions, thereby fostering critical thinking and embodied understanding. UNESCO (2022) emphasizes that such environments, when ethically designed, can enhance inclusive education, particularly for learners who face geographical, physical, or social barriers.

From the perspective of digital humanism, educational metaverse applications reposition learners as co-creators of knowledge rather than passive recipients. This shift aligns with Industry 5.0's emphasis on creativity, empathy, and collaborative intelligence.

Environmental Awareness and Sustainable Development

Digital environments also provide innovative tools for promoting environmental awareness and sustainability. Simulations within the metaverse can visualize climate scenarios, ecosystem dynamics, and the long-term consequences of policy decisions, enabling citizens and decision-makers to grasp abstract environmental data in intuitive and experiential ways (Triantafyllidou & Zabaniotou, 2021). Jaimei et al. (2017) argues that such applications can transform environmental governance by integrating digital participation into sustainability planning. Virtual participatory platforms allow communities to engage in co-design processes for urban resilience, energy transition, and ecological restoration. These practices exemplify digital sustainability in action: technology is not merely optimized for efficiency but employed as a medium for collective ecological responsibility.

Social Innovation, Inclusion, and Community Building

Industry 5.0 emphasizes social cohesion and inclusion as central design principles. In this context, the metaverse can function as a space for social innovation, offering marginalized or geographically isolated groups new opportunities for participation, expression, and community formation (Thompson et al., 2025). Virtual communities of practice enable users to collaborate across cultural and national boundaries, fostering intercultural dialogue and collective problem-solving. Bouzguenda et al. (2019) highlight that such digitally mediated participation can strengthen social capital and reinforce democratic engagement when supported by inclusive governance frameworks. However, these benefits are contingent upon equitable access to technology and the mitigation of digital divides. Without deliberate policies of inclusion, the metaverse risks reproducing existing inequalities rather than overcoming them.

Institutional and Policy-Oriented Applications

Beyond grassroots initiatives, Industry 5.0 principles are increasingly influencing institutional and policy-level applications. Governments and public organizations are experimenting with digital twins, virtual consultations, and immersive policy simulations to enhance transparency and citizen engagement.

Afzalan et al. (2018) suggest that the integration of design thinking into public digital platforms can facilitate participatory policymaking, allowing citizens to visualize trade-offs, test alternatives, and contribute meaningfully to decision-making processes. Such applications illustrate a shift from technocratic governance toward deliberative digital governance, where technology supports, not replaces, democratic institutions.

Domain	Application	Human / Social Dimension	Sources
Education	Immersive learning in the metaverse	Active participation, empathy	Shi & Park (2024), Waquar et al. (2024)
Environment	Digital simulations, “green citizenship”	Climate awareness, collective action	Triantafyllidou & Zabaniotou (2021)
Health	Therapeutic VR environments	Empathy, personal empowerment	Dwivedi et al. (2022), Bibri (2022)
Social Inclusion	Virtual communities, inclusive design	Accessibility, participatory culture	Johnson (2023), Agarwal & Alathur (2023)

Table 2: Application Domains and Human-Centric Impacts of Industry 5.0

CONCLUSIONS AND PERSPECTIVES

The transition from Industry 4.0 to Industry 5.0 marks a critical moment in the contemporary technological paradigm. Rather than representing a linear continuation of automation and digitalization, Industry 5.0 constitutes a normative and cultural reorientation that places the human being, ethical responsibility, and social sustainability at the center of technological development.

This study has argued that the metaverse, as a socio-technological ecosystem, embodies both the promises and the contradictions of this transition. On the one hand, it offers unprecedented opportunities for creativity, participation, education, and collective intelligence. On the other hand, it intensifies existing challenges related to surveillance, data commodification, environmental impact, and digital exclusion. The metaverse thus functions as a critical testing ground for the principles of digital humanism and ethical technology.

A central conclusion of this paper is that digital sustainability cannot be reduced to technical optimization or energy efficiency alone. It must be understood as a holistic framework that integrates ethical design, democratic participation, social justice, and environmental responsibility. Within this framework, technology is no longer perceived as a neutral tool, but as a socio-cultural force that shapes identities, institutions, and values.

Industry 5.0 emerges, therefore, not merely as an industrial strategy but as a cultural project, one that calls for a renewed social contract between humans and technology. This project requires the active involvement of citizens, educators, policymakers, and engineers in the co-creation of technological systems that respect human dignity and promote collective well-being.

From a forward-looking perspective, several key directions emerge as essential for shaping inclusive and sustainable digital futures. First, there is a pressing need for the development of ethical-by-design frameworks that are embedded directly into immersive and algorithmic systems, ensuring that values such as transparency, accountability, and human dignity are incorporated from the earliest stages of technological development. Equally important is the institutionalization of participatory governance mechanisms within digital environments, enabling users and communities to play an active role in decision-making processes that affect their digital lives. At the educational level, the integration of digital citizenship education across both formal and informal learning contexts is crucial, equipping individuals with the critical, civic, and ethical competencies required in complex digital societies. Finally, advancing interdisciplinary research that bridges technology, the humanities, and the social sciences will be fundamental to fostering holistic approaches capable of addressing the multifaceted challenges of contemporary digital transformation.

Ultimately, the success of Industry 5.0 will not be measured by the sophistication of its technologies, but by its capacity to foster trust, inclusion, and sustainability in an increasingly interconnected world. The metaverse, if guided by the principles outlined in this study, can become not a space of escapism, but a shared digital common, a domain where technological innovation serves democratic and human-centered futures.

References

Afzalan, N., & Muller, B. (2018). Online participatory technologies: Opportunities and challenges for enriching participatory planning. *Journal of the American Planning Association*, *84*(2), 162-177. https://doi.org/10.1080/01944363.2018.1434010

Agarwal, A., & Alathur, S. (2023). *Metaverse revolution and the digital transformation: Intersectional analysis of Industry 5.0.Transforming Government: People, Process and Policy, 17*(4), 688–707. https://doi.org/10.1108/TG-03-2023-0036

Albers, M., & Sarlet, I. W. (2024). *Personality and Data Protection Rights on the Internet: Brazilian and German Approaches.* Routledge.

Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). *The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures.Smart Cities, 5*(3), 771–801. https://doi.org/10.3390/smartcities5030040

Aradau, C., & Blanke, T. (2019). *Algorithmic Reason: The New Government of Self and Other.* Routledge.

Arghashi, V. (2024). *Exploring users' fluidity and adaptation in virtual worlds: Metaverse features and interaction of awe and realism.Asia-Pacific Journal of Business Administration.*https://doi.org/10.1108/apjba-05-2024-0303

Bibri, S. E. (2022). *The social shaping of the metaverse as an alternative to the imaginaries of data-driven smart cities.Smart Cities, 5*(3), 832–874. https://doi.org/10.3390/smartcities5030043

Bouzguenda, I., Alalouch, C., & Fava, N. (2019). *Towards smart sustainable cities: The role digital citizen participation could play in advancing social sustainability.Sustainable Cities and Society, 50,* 101627. https://doi.org/10.1016/j.scs.2019.101627

Braidotti, R. (2013). *The Posthuman.* Polity Press.

Chung, D. (2025). Generative AI-Powered Metaverse: The Evolution and Innovation of User-Centered Experiences and Socio-Technical Interactions. *Informatization Policy*, *32*(1), 3-26. https://doi.org/10.22693/NIAIP.2025.32.1.003

Doueihi, M. (2014). *L'identité à l'ère des Digital Humanities.*CNRS Éditions.

Dwivedi, Y. K., Hughes, D. L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., ... & Wamba, S. F. (2022). *Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy.International Journal of Information Management, 66,* 102542. https://doi.org/10.1016/j.ijinfomgt.2022.102542

Elliott, A. (2015). *Identity Troubles: An Introduction.* Routledge.

Ernst, W. (2012). *Digital memory and the archive* (J. Parikka, Ed.). University of Minnesota Press.

Frau-Meigs, D., O'Neill, B., Soriani, A., & Tomé, V. (2021). *Digital Citizenship Education: Overview and New Perspectives.* Council of Europe.

Graham, S., & Wood, D. (2003). *Digitizing surveillance: Categorization, space, inequality.Critical Social Policy, 23*(2), 227–248. https://doi.org/10.1177/0261018303023002006

Huberman, J. (2024). *The Spirit of Digital Capitalism.* University of California Press.

Isin, E. F., & Ruppert, E. (2020). *Being digital citizens* (2nd ed.). Rowman & Littlefield.

Jamei, E., Mortimer, M., Seyedmahmoudian, M., Horan, B., & Stojcevski, A. (2017). Investigating the role of virtual reality in planning for sustainable smart cities. *Sustainability*, *9*(11), Article 2006. https://doi.org/10.3390/su9112006

Johnson, A. (2023). Virtual Reality as a Catalyst in Advancing Inclusive Design for Social and Cultural Sustainability in Architecture. *Int.J.Arch. and Plan*. *3*(2), 1-11. https://doi.org/10.51483/IJARP.3.2.2023.1-11

Jones, S. G. (Ed.). (1998). *CyberSociety 2.0: Revisiting Computer-Mediated Communication and Community.* SAGE Publications.

Kalemis, A. (2025a). *Metaverse as a field of communication and networking in the digital domain: Challenges and prospects.* In *Envisioning the Future of Communication – Conference Proceedings*, *2*(1), 163–176. https://doi.org/10.12681/efoc.7904

Kalemis, A. (2025b). *Η Χωρική Εκπαίδευση στη Σύγχρονη Ψηφιακή Παγκοσμιότητα: Προκλήσεις και Προοπτικές στην Ανθρωπόκαινο Εποχή* [Spatial education in modern

digital universality: Challenges and prospects in the Anthropocene era]. *Mentoras*, 23(1), 150–163. https://ejournals.epublishing.ekt.gr/index.php/mentoras/article/view/40581/31854 (accessed 24 Dec 2025)

Katzenbach, C., & Ulbricht, L. (2019). *Algorithmic governance.Internet Policy Review, 8*(4), 1–18. https://doi.org/10.14763/2019.4.1424

Kravchenko, N., Chaika, O., Yudenko, O., & Muntian, O. (2025). *Liminality and the metaverse: An analysis of mytho-liminal and mystic-liminal games and their impact on player identity.Metaverse, 6*(1), Article 3102. https://doi.org/10.54517/m3102

Lee, L. H., Braud, T., Zhou, P. Y., Wang, L., Xu, D., Lin, Z., ... & Hui, P. (2024). *All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda.Foundations and Trends® in Human-Computer Interaction, 18*(2–3), 100–337. https://doi.org/10.48550/arXiv.2110.05352

Lozano-Díaz, A., Figueredo-Canosa, V., & Fernández-Prados, J. S. (2020, March). Sustainable development goals and digital citizenship. In *Proceedings of the 2020 8th International Conference on Information and Education Technology* (pp. 212-215). https://doi.org/10.1145/3395245.3396431

Mohammed, R., Bayrisetti, P. B., Aggala, C., Subramanya, S. S., Bunga, K. K., Mohammed, S., Jarabala, R., & Saride, J. M. (2026). *Human-centric innovations and sustainable transformations: Bridging Industry 5.0 and Society 5.0 for smart manufacturing and resilient communities* (in *AI and Digital Nomads Shaping Global Industrial Technology Transitions*, pp. 237–263). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-0159-4.ch007

Polizzi, G. (2020). *Information literacy in the digital age: Why critical digital literacy matters for democracy* (in S. Goldstein, Ed.), *Informed societies: Why information literacy matters for citizenship, participation and democracy* (pp. 1–23). Facet Publishing. https://researchonline.lse.ac.uk/id/eprint/102993/ (accessed 12 Aug 2025).

Robinson, L., Schulz, J., Dunn, H. S., Casilli, A. A., Tubaro, P., Carvath, R., Chen, W., Wiest, J. B., Dodel, M., Stern, M. J., Ball, C., Huang, K.-T., Blank, G., Ragnedda, M., Ono, H., Hogan, B., Mesch, G. S., Cotten, S. R., Kretchmer, S. B., … Khilnani, A. (2020). *Digital inequalities 3.0: Emergent inequalities in the information age.First Monday, 25*(7). https://doi.org/10.5210/fm.v25i7.10844

Robison, W. L. (2024). *Ethics within engineering: An introduction*. Bloomsbury Publishing.

Salimova, T., Vuković, N., & Guskova, N. (2020). *Towards sustainability through Industry 4.0 and Society 5.0.International Review*, 3–4, 48–54. https://doi.org/10.5937/intrev2003048S

Shakeri, S., & Ornek, M. A. (2023). *How metaverse evolves the architectural design.Architecture and Planning Journal, 28*(3), 35. https://doi.org/10.54729/2789-8547.1230

Shi, C., & Park, J. Y. (2024). A systematic review of the Metaverse in formal education. *Journal of Applied Research in Higher Education*. https://doi.org/10.1108/JARHE-04-2024-0162

Skinner-Thompson, S. (2024). *Privacy at the Margins.* Harvard Law Review.

Suryawinata, B. A. (2021). Immersive Technology as A Tool for Sustainable Architecture. In *IOP Conference Series: Earth and Environmental Science* (Vol. 794, No. 1, p. 012185). IOP Publishing. https://doi.org/10.1088/1755-1315/794/1/012185

Tapias, B. H., Guzmán, D. H., Muñoz, P. C., & Duarte, N. R. (2024). *Digital Citizenship and Sustainable Governance: A Design Thinking Approach.Procedia Computer Science, 231,* 78–85. https://doi.org/10.1016/j.procs.2023.12.175

Thompson-Bahm, H., Teixeira, J. E., & Lobo, R. C. G. (2025). *Enhancing sustainability and human centricity through emerging technologies from Industry 4.0 to Industry 5.0: An*

integrative literature review.Corporate Governance and Sustainability Review, *9*(3), 90–104. https://doi.org/10.22495/cgsrv9i3p7

Triantafyllidou, E., & Zabaniotou, A. (2021). *Digital technology and social innovation promoting a green citizenship: Development of the "go sustainable living" digital application.Circular Economy and Sustainability,* 1–24. https://doi.org/10.1007/s43615-021-00111-3

Tsili, P. (2016). *Κοινωνιολογία του ελληνικού κυβερνοχώρου: Διαδικτυακές ταυτότητες και εικονική πραγματικότητα* [Sociology of greek cyberspace: on line identities and virtual reality]. PhD Thesis. Panteion University, Athens. http://dx.doi.org/10.12681/eadd/39894

UNESCO. (2022). *Citizenship Education in the Global Digital Age.* UNESCO Publishing. Available at https://unesdoc.unesco.org/ark:/48223/pf0000381534 (Accessed 20 Jan 2026).

Van Dijck, J. (2013). *The Culture of Connectivity: A Critical History of Social Media.* Oxford University Press.

Waquar, A., Kareem, S., Yasmeen, N., & Hussain, S. (2024). From traditional to virtual classrooms: unravelling themes and shaping the future of metaverse education. *Interactive Technology and Smart Education*. https://doi.org/10.1108/ITSE-02-2024-0032.

Werthner, H., Ghezzi, C., Kramer, J., Nida-Rümelin, J., Nuseibeh, B., Prem, E., & Stanger, A. (2024). *Introduction to Digital Humanism: A Textbook.* Springer.

Yeung, K., & Lodge, M. (2024). *Algorithmic Regulation.* Oxford University Press.