

Special Issue
Engineering the Future Sociologically:
a Call to Delve into Environmental
Education Enhanced by
Technological Innovations

FUORI LUOGO

**Journal of Sociology of Territory,
Tourism, Technology**

Guest Editors

Norberto Albano
Sandro Brignone
Carmine Urciuoli



Editor in Chief: Fabio Corbisiero
Managing Editor: Carmine Urciuoli

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Learning Cities and Urban Ecosystems. Digital Technologies Fostering Informal Lifelong Environmental Education in Cities and Urban Participation²

Introduction

The ecological crisis is a pivotal element in a context of intertwined societal, economic, and environmental disequilibrium, conceptualized by Morin and Kern (1999) through the notion of "polycrisis". As the authors point out, these approaches must foster a holistic understanding of reality, recognizing that solutions to one crisis can create ripple effects on others. Comprehending the «*complexities of the environment*» and recognizing the urgency to adapt «*human activities and development in ways which are harmonious with the environment*» represent the ultimate aim of Environmental Education, as stated in the final report of the First Intergovernmental Conference on Environmental Education (UNESCO & UNEP, 1977, p.12). Environmental Education (EE) can increase society's capacity to understand the anthropogenic impact of human activity, addressing the objectives of awareness, knowledge, attitudes, skills, and participation (*ibid.*, p.26). Education should not be confined to younger generations, but should instead adopt a lifelong learning approach, addressing individuals of all ages (UNESCO, 2022). This approach should integrate formal, non-formal, and informal learning models (Coombs *et al.*, 1973; UNESCO, 2016). In particular, informal education takes place through everyday experiences and interactions, encompassing self-directed, family-directed, and socially-directed learning within workplaces, families, and communities (*ibid.*). The notion of informal education in urban contexts is particularly broad, encompassing a wide range of activities, including various forms of outdoor learning. The UNESCO Institute for Lifelong Learning (2015) has introduced the concept of "Learning Cities" to highlight the role of cities in the promotion of lifelong and inclusive learning that can address a large share of citizens, through non-formal and informal models. This includes diverse forms of outdoor learning (Chawla, 2020; Dennis *et al.*, 2017), civic ecology and participation (Tidball *et al.*, 2011; Krasny *et al.*, 2015), citizen science (Dickinson *et al.*, 2012), and games or serious games (Tan *et al.*, 2023).

Educational approaches are strictly tied to both societal contexts and the technologies and tools that can enable them. In the last few decades, the growth of Information and Communication Technologies (ICTs), usually defined as digital technologies, has brought structural changes to each aspect of human life, requiring educators to develop new approaches, take advantage of new tools, and face unprecedented challenges (EU, 2020). The capacity of ICTs to transform and foster EE has been the subject of several studies (UNESCO, 2023; Lowan-Trudeau, 2023; Lynch & Thomas, 2024; Hajj-Hassan *et al.*, 2024). However, research has focused mainly on formal and non-formal approaches, and there is limited knowledge about how ICTs can support and enhance informal Environmental Education, particularly in urban contexts, where opportunities for informal learning are abundant but underexplored. This gap highlights the need to better understand how digital technologies can be mobilized to foster environmental awareness, engagement, and action through informal learning processes in cities.

Building on these observations, the paper formulates two key research questions. First, which functionalities of different digital technologies can enhance informal Environmental Education (EE) in urban contexts? Second, how can these functionalities contribute to the achievement of key EE objectives, as defined by UNESCO & UNEP (1977, *op. cit.*)?

To address these questions, the paper investigates the potential of digital technologies to both support and innovate informal EE in urban environments. The research follows a structured

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methodology articulated in three main phases. In the first phase, the paper reviews the relevant state of the art, defines its theoretical framework, and establishes its analytical framework by identifying the key educational objectives and the technological functionalities under investigation.

In the second phase, the paper conducts a focused review of the literature concerning three specific digital technologies—Augmented Reality (AR), Participatory Platforms, and video mapping—with the aim of identifying which of these technologies’ functionalities can contribute to achieving the identified educational objectives in urban contexts. The third phase delves deeper into the two technologies that emerge as particularly promising—participatory platforms and video mapping—by conducting an in-depth analysis of two innovative case studies. This analysis, based on qualitative data and interviews with designers, provides critical insights into the concrete mechanisms through which these technologies can foster informal EE in urban settings.

1. State of Art

1.1 Approaches to Environmental Education

The relevance of EE has grown alongside the awareness of ecological crises and its ties with economic and social development. The Tbilisi Declaration from the “First Intergovernmental Conference on Environmental Education” (UNESCO & UNEP, 1977, *op. cit.*) advocates for EE across all age groups, beyond formal models, supporting holistic, interdisciplinary knowledge, and encouraging activism and participation. It identifies five categories of EE objectives: “(i) *awareness*, to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems; (ii) *knowledge*, to help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems; (iii) *attitudes*, to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection; (iv) *skills*, to help social groups and individuals acquire the skills for identifying and solving environmental problems; (v) *participation*, to provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems” (p. 26).

Environmental Education (EE) goes beyond natural sciences, adopting a transversal and holistic approach that integrates social sciences, economics, politics, ethics, arts, health, technology, and engineering. It promotes a comprehensive understanding of environmental issues, fostering sustainable solutions that balance ecological, social, economic, and cultural dimensions, preparing individuals to act responsibly for planetary well-being. EE focuses on people and socio-ecological relationships rather than nature in isolation (Tilbury, 2011), aligning with *Education for Sustainable development* (UNESCO, 2021) and *Education for Sustainability* (Sterling, 2001).

Salomone (2012) identifies two contrasting visions of sustainable education: a mechanistic vision, focused on economic sustainability, competition, specialization, and standardized outcomes, and an ecological vision, which promotes participation, lifelong learning, inclusion, cooperation, and holistic understanding of sustainability across environmental, social, and economic dimensions. These two approaches reflect deeper, opposing views of the human-nature relationship, as described by Bateson (1979). The mechanistic view is human-centric, rooted in Cartesian dualism, which separates mind and body and sees nature as something to be controlled. The ecological view, in contrast, is ecocentric, rejecting this separation and recognizing humans as part of a complex, interdependent natural system.

The report *No Limits to Learning* (Botkin *et al.*, 1979) emphasizes the existence of a “human gap”, a fundamental lack of understanding of the intricate links between humans and ecosystems. To

close this gap, the report advocates for lifelong and anticipatory learning, not just as a reaction to crises but as a proactive process for fostering ecological awareness, adaptive capacity, active citizenship, and broad participation in environmental action.

In light of this multidimensional understanding of Environmental Education, it becomes clear that the five key objectives identified by UNESCO & UNEP (1977, *op. cit.*) cannot be effectively achieved without fully embracing diverse informal education approaches. While formal education follows structured curricula within schools and universities, and non-formal education includes organized learning outside traditional institutions, informal education unfolds naturally within everyday life, embedded in ordinary experiences, social interactions, and engagement with the environment. This makes informal education particularly strategic in urban contexts, where environmental challenges and values are immediately visible and deeply connected to daily life, offering continuous opportunities for situated and experiential learning.

1.2 Role of cities for Environmental Education

Cities play a crucial role in shaping the challenges and opportunities of Environmental Education (EE). Urban areas are not only sites of environmental impact, but also key spaces where ecological awareness and learning processes can unfold. In this sense, cities can be understood simultaneously as educational subjects, learning environments, and arenas for citizen empowerment. Firstly, cities themselves are complex ecosystems, with non-linear dynamics and intricate relationships between biotic communities (humans, animals, plants) and their abiotic environment (Mostafavi & Doherty, 2010). This complexity reflects the evolving relationship between human communities and their territories (Magnaghi, 2020) shaped by processes of stewardship, adaptation, and transformation. Urban landscapes, as expressions of both cultural and ecological biodiversity, constitute a fundamental educational heritage (UNESCO, 2001). Furthermore, cities play a crucial role in ecological transition due to their significant anthropogenic impact, including climate change, biodiversity loss, and pollution, but urban rigidity and lack of resilience pose challenges to transitional processes. Such transitions require not only environmental awareness, but also transformations in spatial organization, infrastructure, and local economies, as well as the promotion of sustainable lifestyles.

At the same time, cities represent the primary natural environment experienced by much of the global population, especially for socially and economically disadvantaged groups. For many urban dwellers, particularly those with limited mobility or economic resources, natural experiences are often confined to heavily anthropized environments such as parks, green infrastructure, or urban gardens, rather than remote rural landscapes or protected natural areas. This makes the urban environment itself a critical platform for environmental learning, where public spaces become informal arenas for ecological interaction (Gallay *et al.*, 2020; Warren *et al.*, 2014). Recognizing the educational potential of these spaces underscores the importance of integrating ecological knowledge and sustainable practices directly into urban fabric and everyday life.

This perspective aligns with the broader notion of informal education in cities, which encompasses a wide array of activities and approaches that go beyond traditional classroom-based learning. Informal environmental education in urban areas includes diverse forms of outdoor learning (Chawla, 2020; Dennis *et al.*, 2017), where public parks, green corridors, and community gardens become sites for experiential ecological learning. It also embraces practices of civic ecology and participatory action (Tidball *et al.*, 2011; Krasny *et al.*, 2015), fostering environmental stewardship through hands-on community projects such as urban reforestation, neighborhood greening, and waste reduction initiatives.

In this context, informal learning opportunities become crucial tools for fostering ecological awareness and agency in urban populations. Citizen science projects (Dickinson *et al.*, 2012) further extend this educational approach, empowering residents to contribute directly to environ-

mental monitoring and data collection while enhancing their ecological literacy. At the same time, games and serious games (Tan *et al.*, 2023) offer playful and immersive ways to explore urban environmental challenges, turning streets, squares, and digital platforms into learning arenas where participants collaboratively explore solutions to climate change, biodiversity loss, and pollution. By embedding these participatory and playful approaches into the urban experience, cities can actively foster ecological citizenship, turning environmental learning into a shared and collective urban practice.

With the concept of “Learning Cities”, the UNESCO Institute for Lifelong Learning promotes life-long learning opportunities that encompass formal, non-formal, and informal education in cities. The objective of a Learning City is to facilitate access to diverse learning contexts, including community centers, libraries, public spaces, and digital platforms, thereby empowering citizens to engage in continuous environmental education and sustainable practices. This challenge can be supported by an extended use of digital technologies (UNESCO Institute for Lifelong Learning, 2015). In the following chapter, we discuss the transformative role of digital technologies in cities and in educational approaches.

1.3 Digital Technologies as drivers of transformation in the city and in education

The transformative role of ICTs has reshaped both education and urban planning, enhancing engagement, immersion, interaction, and access to information. As part of broader socio-technical systems (Latour, 2005; Mumford, 2006), digital technologies are not neutral tools but evolve with-in social contexts, shaping and being shaped by cultural practices and institutional frameworks. ICTs have also become integral to the functioning and evolution of contemporary cities, driving transformations across various dimensions of urban systems. The Smart City paradigm highlights their role in optimizing infrastructure, although it has also been criticized for its technocratic bias, which often overlooks social and cultural dimensions (Kitchin, 2022). Despite these critiques, digital tools can foster more transparent governance and active citizen engagement, enhancing access to environmental data and supporting collaborative decision-making.

In education, a similar transformative role of ICTs can be recognized. According to the 2023 Global Education Monitoring Report (UNESCO, 2023), digital interfaces - which include video players, tablets, Augmented Reality (AR), Virtual Reality (VR), virtual classrooms, and collaborative platforms - can enhance formal learning experiences if they are carefully integrated with traditional teaching methods, rather than replacing them entirely. This hybrid approach, often referred to as *blended learning* (Graham, 2006), has shown promising results in fostering student engagement, promoting immersive and experiential learning, and simulating complex processes that would otherwise be difficult to reproduce in physical classrooms (Alam *et al.*, 2025).

One of the most significant innovations in ICT-based education is the rise of adaptive learning platforms, which use Artificial Intelligence (AI) and learning analytics to personalize educational pathways based on students’ behavior and performance (Baker & Siemens, 2014). While these tools can support teachers and enhance learning, excessive reliance on them risks promoting passive consumption and limiting the development of critical thinking and creativity (Selwyn, 2016).

ICTs also play a key role in non-formal and lifelong learning, expanding access to knowledge through Massive Open Online Courses (MOOCs) and learning apps. These platforms enable learners from diverse backgrounds, including marginalized groups, to access educational content that might otherwise be out of reach (Sarma & Yoquinto, 2020). Moreover, digital ecosystems support self-directed learning, allowing individuals to build skills on demand (Schmidt-Hertha *et al.*, 2021). However, challenges remain, including digital divides, privacy concerns, and questions about long-term costs and the actual effectiveness of digital learning (UNESCO, 2023, *op. cit.*).

In the context of informal education, digital platforms are recognized as key enablers of citizen science processes for sharing crowd-sourced information, interacting, and accessing sectoral

knowledge (Dickinson *et al.*, 2012, *op. cit.*; Mahajan *et al.*, 2020). Furthermore, digital interfaces can enhance various social or individual activity by providing access to data and information, simulating conditions, or providing immersive experiences.

In summary, digital technologies represent tools, or enablers, capable of augmenting or fostering all types of educational activities. Four key functionalities of digital technologies for education can be identified: (i) providing immersive experiences, (ii) simulating diverse conditions related to variables, (iii) sharing information through the overlap or integration of informative layers and allowing interaction, and (iv) increasing accessibility to educational content.

The strength and impact of these functionalities can vary depending on the specific digital technologies used and the educational objectives pursued. However, the literature lacks structured and systematic knowledge on how this occurs in the context of informal Environmental Education. To address this gap, the following section delves into a targeted literature review focused on three specific digital technologies—Augmented Reality (AR), Participatory Platforms, and video mapping. The analysis explores the impact of the four functionalities in urban informal education contexts, and how they can contribute to achieving specific EE objectives.

2. Digital technologies for environmental education in cities: opportunities for informal learning

An analysis of the state of the art shows the key role of cities in informal Environmental Education, acting as educational subjects, learning environments, and arenas for citizen empowerment. It also defines the analytical framework adopted in this chapter to examine three digital technologies—Augmented Reality, Participatory Platforms, and video mapping. The analytical framework combines five educational objectives (awareness, knowledge, attitudes, skills, and participation) with four core functionalities of digital technologies (immersive experiences, simulation, integration of informative layers and interaction, and accessibility).

2.1 Augmented Reality

Augmented Reality (AR) works by recognizing physical objects or locations and overlaying them with digital information, allowing users to interact with virtual elements while staying aware of their real surroundings. There are two main approaches: object-based AR, which overlays information on small objects, and location-based AR, which integrates content into broader environments (Billinghurst *et al.*, 2015). Geroimenko (2020) highlights AR's growing role in education, particularly for immersive, collaborative learning experiences. According to Ducasse (2020), AR is especially effective in environmental education (EE) when combined with outdoor learning, helping users explore nature by enhancing direct observation and curiosity with digital content (Fang *et al.*, 2022).

Urban systems become both the object and environment for EE through AR. Several projects illustrate this potential. EduPARK, implemented in Portugal, features modes for free exploration and educational games, aiming to promote cross-disciplinary learning and user-friendly interaction. AR markers on plant labels and historical signage trigger digital content, including interactive challenges and treasure hunts. The game has been tested with students and teachers, but according to the authors, it can be used by citizens and tourists, providing activities and an alternative experience within urban parks. A similar strategy was developed by Kamarainen *et al.* (2018) with the project EcoMOBILE that explored various physical environments and subject areas, focusing on undergraduate students of Ecology and Environmental Science. A non-formal educational experience was developed through the app Pipi's World (Aguayo *et al.*, 2020), created for a marine educational center in New Zealand. The app uses AR to engage students

visiting the center, guiding them through digital learning experiences with the help of a character. According to the authors, the interface was observed to increase engagement and convey content relevant to EE, although it required a facilitator, as some users found it difficult to navigate. Similarly, the artist Tamiko Thiel used AR in her project Wild Garden, overlaying oversized flowers and plants onto a museum garden in Munich, creating an immersive experience that invited reflection on ecological relationships in the Anthropocene (Iovino, 2019).

Accessibility issues, app downloads, and site-specific costs are key barriers to using these interfaces for informal learning in open urban spaces. However, plant identification apps using real-time camera framing and object-based AR are increasingly popular. These apps spark curiosity and support informal learning about urban biodiversity, but they rarely convey deeper ecological complexity. Further development, supported by public-private partnerships or public funding, could enhance their educational depth and promote wider ecological awareness in urban areas. Reaver *et al.* (2023) describe a participatory AR experience for urban tree-planting in Oslo. The location-based interface allowed users to simulate different tree configurations by overlaying 3D models onto real urban spaces captured by the camera. This interactive process gave users an active role, improving their understanding of possible solutions. The authors found the technology highly effective for engaging users in EE, promoting stewardship, and developing skills, but noted challenges in app development and technical instability caused by the complexity of location-based recognition.

Based on these observations, the impact of Augmented Reality can be assessed across the four key functionalities of the analytical framework. AR has strong potential to provide immersive experiences by overlaying digital content onto physical environments by blending virtual and real elements into seamless educational interactions. It also supports scenario simulation, allowing users to explore different environmental configurations, as shown in EcoMOBILE and Oslo's tree-planting project. AR effectively integrates digital information with physical objects through interactive layers triggered by visual markers, as demonstrated in EduPARK. However, its accessibility remains low due to the need for specific apps, site-specific content, and compatible devices, limiting its potential for spontaneous and large-scale informal learning in cities.

When evaluated against the five key objectives of Environmental Education (UNESCO & UNEP, 1977, *op. cit.*), Augmented Reality shows strong potential for fostering awareness and knowledge by overlaying environmental information onto real-world elements, enhancing observation and curiosity (Geroimenko, 2020; Pombo & Marques, 2019). However, much of this content remains superficial, focusing on facts rather than encouraging critical reflection or systems thinking (Aguayo *et al.*, 2020). AR can also foster attitudes through immersive engagement, but this depends heavily on narrative design and the ability to link content to personal and collective meaning (Iovino, 2019). It supports spatial interpretation and environmental observation skills but has a limited potential to develop critical thinking when users passively consume predefined content (Kamarainen *et al.*, 2018). Finally, while AR can enhance participation through co-creation processes, as seen in Reaver *et al.* (2023), technical barriers, app requirements, and uneven digital literacy hinder its potential as an accessible tool for informal urban learning.

2.2 Digital Participatory Platforms

Participation is a broad concept spanning multiple fields. In education, it serves as a key pedagogical strategy, fostering awareness, creativity, and transformative learning through active involvement and collaboration (Botkin *et al.*, 1979). In urban governance, participation refers to inclusive processes where citizens help shape plans, policies, and projects, promoting equity, transparency, and effectiveness.

This civic participation also has educational value, as citizens involved in environmental decisions develop thematic skills, critical thinking, and environmental awareness (Peeters, 2017). However,

effective participation-based environmental education requires strong environmental literacy among both facilitators and participants—often lacking in contexts where administrative capacity and participatory traditions are weak.

A valuable contribution can emerge from horizontal participation processes, such as the collaborative management of urban commons, which foster collective intelligence and encourage sustainable governance practices (Ostrom, 1990; Peeters, 2017). In both top-down and bottom-up processes, digital technologies can play a crucial enabling role, enhancing information sharing, facilitating interaction, and supporting citizen science initiatives (Bonney *et al.*, 2014). Digital participatory platforms expand opportunities for informal environmental education, particularly during community engagement activities such as workshops, urban planning labs, or local environmental monitoring projects. Through these platforms, citizens access information, contribute data, and engage in collaborative decision-making, thus combining participation with informal learning.

A relevant case is Decidim, an open-source platform developed by the City of Barcelona and now adopted internationally (García *et al.*, 2023). Decidim supports participatory budgeting, public consultation, collaborative proposal writing, and accountability tracking, fostering transparency and sustained citizen engagement. One of its key priorities is the ecological transition, embedding environmental awareness across all participatory processes. This integrated approach exemplifies how participatory democracy can intersect with environmental education, turning participatory platforms into tools for informal learning. However, many other platforms remain fragmented, limited to isolated functions such as survey collection or information dissemination (Gil *et al.*, 2019). While these tools may offer customized solutions, they lack the holistic educational potential seen in more systemic platforms that explicitly link participation, environmental awareness, and collective action. In this sense, the design of participatory platforms themselves becomes an educational choice, shaping whether digital tools simply manage participation—or actually nurture environmental knowledge, values, and active citizenship.

In terms of objectives, digital participatory platforms enhance environmental awareness by providing access to data and visualizing local issues, though the quality of awareness depends on whether the information fosters critical ecological literacy or simply presents consultation data. Their contribution to knowledge development is stronger when they support collaborative processes and citizen science, enabling users to collect and interpret data, but this potential is weakened when platforms focus more on procedural efficiency than educational depth. Participation can foster pro-environmental attitudes by strengthening place attachment and collective responsibility, although platforms that reduce environmental issues to technical problems weaken this potential. Platforms also build skills, particularly when citizens engage directly in negotiation and decision-making, but consultative approaches—where users only answer predefined questions—limit the development of critical and analytical skills.

Assessing the functionalities of participatory platforms, we can conclude that they are rarely immersive, relying mostly on text and data, though some use multimedia to enrich the experience. They can simulate environmental scenarios to show decision impacts, but this varies across tools. Their main strength is the integration of diverse information layers—combining citizen input, environmental data, and policy documents into shared knowledge (García *et al.*, 2023). However, accessibility is hindered by digital divides, language barriers, and the need for facilitation, especially in excluded communities.

2.3 Video mapping

It is widely recognized that art has the capacity to provoke reflection, stimulate awareness, inspire activism, and denounce societal problems. Art installations in cities play a key role in promoting environmental awareness, incorporating digital technologies to create interactive, im-

mersive, and thought-provoking experiences, making complex concepts more accessible and impactful. This type of experiential learning can be more effective than traditional methods in raising awareness and inspiring action (Miles, 2014). Art installations can also reach a broad audience due to their accessibility, as they are easily integrated into public spaces, museums, and educational institutions.

Digital technologies can amplify these processes, integrating innovative tools such as video mapping, sound design, high-performance computing, simulation, and visualization. By embedding EE directly into the urban environment, these technologies can foster a sense of community and collective responsibility (Fenner, 2017). Video mapping, also known as projection mapping, involves projecting images and videos onto physical surfaces to create dynamic visual displays. It is often combined with sound, creating multisensory and immersive experiences. Like AR, it overlays images, data, and information onto physical objects, but does not require individual devices or digital skills to access (Derkach *et al.*, 2023). By projecting visualizations of climate change, pollution, and biodiversity loss onto buildings, landscapes, or other urban surfaces, video mapping can make these issues more immediate and emotionally engaging, fostering stronger connections to environmental challenges.

An interesting case study is the immersive installation “Foresta Lumina”, which offers a nighttime sensory experience in a woodland park in Canada. Through light, projections, sound, and storytelling, it explores local myths and cultural heritage, while also creating an immersive nature-based experience. Although not explicitly designed for environmental education, it effectively draws visitors into an outdoor ecological scenario, demonstrating through art the complexity of ecological networks (Desrochers Ayotte, 2018). Another example is “Evolution of Fish” by Thiel (2020), which used video mapping combined with AR to project a swarm of fish onto a residential building, allowing participants to interact and alter the swarm’s behavior, introducing an interactive simulation of ecological dynamics. The project “RO_map”, a projection mapping project held in Rome, explored how dynamic video projections can enhance the perception of the urban landscape. By projecting digital content onto building facades, the installation responded to the speed and position of passing viewers, adapting its visual messages to the flow of urban mobility (Empler, 2017). This adaptive approach aimed to make environmental and spatial information more visible and context-aware, connecting place perception with ecological awareness. Although not exclusively dedicated to environmental education, it shows how urban video mapping can transform public space into a platform for situated, informal learning, encouraging reflection on urban transformations and their environmental dimensions.

However, the scientific literature only offers a limited number of cases that explicitly focus on environmental education through video mapping, leaving this potential underexplored.

Assessing video mapping through the analytical framework implemented here, its contribution to awareness is particularly strong, as it offers immediate and impactful visual narratives embedded directly in the urban landscape. The potential to develop knowledge is present but depends heavily on content design—often leaning toward artistic spectacle rather than structured ecological learning. In fostering attitudes, video mapping can trigger emotional responses and place attachment, but this is highly variable, especially in projects without clear educational intent. It offers limited space for skill development, since the public typically experiences rather than co-creates the content. Participation is largely passive, with audiences receiving messages rather than actively contributing, though participatory design processes could expand this role. In terms of functionalities, video mapping excels at creating immersive experiences, can simulate dynamic processes like environmental change, and integrates multiple information layers into cohesive experiences. Its accessibility is also high, requiring no devices or prior knowledge, but the educational depth remains contingent on how intentionally environmental themes are addressed.

2.4 Discussion

The comparative analysis in the previous section shows the significant potential of digital technologies to foster informal EE in urban contexts. Each of the three technologies—Augmented Reality (AR), digital participatory platforms, and video mapping—demonstrates distinct capacities and limitations when evaluated against the analytical framework of educational objectives and technological functionalities.

Augmented Reality offers strong immersive and interactive experiences, blending digital content with real-world elements, making environmental data tangible and site-specific. It also supports simulation of alternative scenarios, fostering exploratory learning. However, low accessibility remains a critical limitation: the need for dedicated apps, compatible devices, technical expertise, and site-specific customization significantly reduces AR's potential for spontaneous, large-scale informal education in public urban spaces. Its impact relies heavily on structured facilitation or project-specific funding, limiting its diffusion.

Digital Participatory Platforms show high potential for integration and interaction, particularly when they embed citizen science initiatives or collaborative decision-making processes. Their contribution to knowledge development and awareness can be significant, especially when environmental data is visualized in accessible formats and linked to policy debates. However, their limited immersiveness and barriers to access—due to digital divides, language issues, or unfamiliarity with participatory processes—reduce their ability to reach the broader urban population.

Video mapping, while less common in environmental education, emerges as the most accessible and immersive technology in public urban settings. It requires no personal device, has low entry barriers for audiences, and transforms urban surfaces into educational media. Its capacity for simulation and integration of information layers is notable, especially when environmental data is embedded into visual storytelling. However, the educational depth of video mapping remains limited in practice, as most examples focus on artistic spectacle rather than structured environmental literacy. The literature lacks systematic examples where video mapping is explicitly designed to deliver multi-dimensional environmental education aligned with the five EE objectives (awareness, knowledge, attitudes, skills, participation).

In summary, video mapping and participatory platforms stand out as the most promising technologies for fostering widespread informal EE in urban contexts, due to their broad accessibility and potential for engagement in public spaces. However, realizing this potential requires intentional content design, ensuring that awareness-raising efforts go beyond basic consultation and actively foster critical ecological literacy, skills development, and meaningful citizen participation. These insights provide the foundation for the next chapter, which examines two case studies that apply participatory platforms and video mapping to informal environmental education, assessing their effectiveness against the analytical framework of objectives and functionalities.

3. Case study analysis

Building on the reflections developed in the previous chapter, this section presents two case studies selected to further investigate how digital participatory platforms and video mapping can contribute to informal Environmental Education (EE) in urban contexts. The case studies have been chosen for their innovative use of digital technologies, their relevance to environmental themes, and their capacity to engage diverse urban audiences. Each case will be analyzed through the analytical framework, evaluating its alignment with the five educational objectives (awareness, knowledge, attitudes, skills, participation) and its performance across the four key functionalities (immersion, simulation, integration and interaction, accessibility).

3.1 Superbarrio

Superbarrio is a gamified digital participatory platform designed to engage citizens of all ages in the co-design of public spaces, combining playful interaction with collaborative urban planning. Through a 3D interface, users can visualize public spaces, place functional modules (such as green areas, benches, and mobility infrastructure), and assess their impact on categories such as nature, well-being, health, mobility, participation and economy. Players must balance these variables, thereby fostering reflection on the complex interdependencies shaping urban systems (Markopoulou *et al.*, 2018). Data is collected to support the technical evaluation of design proposals but also serves an educational purpose, helping participants understand the criteria, trade-offs, and conflicts inherent in environmental and spatial decision-making. In this way, Superbarrio aims to function as a civic education tool, helping citizens recognize public space as a site of negotiation between diverse needs, and encouraging learning about sustainability solutions that are both inclusive and viable long-term.

Originally developed in 2017 and tested in Barcelona, Genoa, and Favara, the platform evolved within the URBINAT project (Horizon 2020), focusing on the co-creation of Healthy Corridors through Nature-Based Solutions (NBS) in underprivileged urban areas. In this context, Superbarrio acted as both a participatory tool and an informal educational platform, helping citizens understand the ecological, social, and economic dimensions of environmental regeneration (Markopoulou *et al.*, 2022). The first test, conducted at the Nantes médiathèque with 50 citizens, showed positive results, demonstrating the app's high capacity for prolonged engagement, accessibility, and effectiveness in increasing awareness, understanding, and agency on complex urban-ecological issues. These included: conflicts between stakeholders, the systemic impact of individual actions, environmental fragilities in urban contexts, ecosystem services, NBS management skills, and health and well-being in cities (Markopoulou *et al.*, 2022).

The platform's educational value is embedded in its design. By involving participants in decision-making processes, it raises awareness of environmental issues, promotes systems thinking, and fosters skills related to ecological design and conflict mediation. Its gamified structure makes it particularly effective at attracting non-traditional audiences (including children and non-habitual participants), creating what project leaders call an "audience-by-surprise" effect. This makes Superbarrio not just a tool for participatory planning, but also a potential vehicle for lifelong environmental learning in urban settings.

Project leaders highlight that the platform's full potential for widespread environmental education could be further enhanced if municipalities and public institutions actively support its deployment, not only in the context of formal participatory processes, but also as a standalone educational game, fostering environmental literacy in public spaces, schools, and cultural events. The assessment based on the EE objectives shows that Superbarrio contributes to awareness by making environmental challenges and their connection to urban design visible and explicit throughout the game. Players develop knowledge through experiential learning, gaining a better understanding of NBSs, ecosystem services, and the systemic impacts of spatial decisions (Markopoulou *et al.*, 2018, 2022). The platform fosters pro-environmental attitudes by encouraging players to balance diverse needs, recognize conflicts, and take responsibility for collective decisions. It enhances skills, from spatial planning to critical thinking, negotiation, and understanding environmental data. Finally, participation is at the core of the process, as users actively co-design solutions while learning how to participate in urban governance. Superbarrio's immersive 3D environment, real-time simulation, and integration of data and design tools make learning intuitive and engaging. Its high accessibility—thanks to simple mechanics and playful design—thereby extending participation to diverse audiences, including children and first-time participants.

The assessment based on the digital functionalities confirms Superbarrio's potential for informal environmental education. Its immersive experience relies on a 3D interface, which allows

users to visualize and modify urban spaces in real time, directly linking environmental choices to spatial design outcomes. The platform is able to simulate realistic scenarios by showing how each design decision influences environmental and social indicators, helping participants grasp cause-effect relationships within urban ecosystems. A key strength lies in its integration of information and interactivity, as the platform combines environmental data, citizen inputs, design options, and feedback mechanisms within a single interactive environment. Finally, accessibility is relatively high due to intuitive navigation and simple mechanics, combined with a playful format that encourages participation from a broad range of users, including those with limited familiarity with environmental topics or participatory processes.

3.2 *Anima Mundi*

The project *Anima Mundi* was an experiential art installation event hosted during the summer of 2021 at the Orto Botanico of Palermo, a historic botanical garden near the city center and located in an area characterized by high tourist flows and vibrant nightlife. The installation offered visitors a nighttime journey through nine stops, each associated with a specific plant species—e.g. *Ficus macrophylla* and *Nelumbo nucifera*—and connected to structures such as greenhouses, ponds, and historic paths. Using advanced audiovisual technologies, particularly video mapping, combined with animated 2D graphics and sound design, *Anima Mundi* created an immersive storytelling experience in which visitors explored the garden through the voices and stories of five fictional characters.

The narrative unfolded around themes of care and responsibility toward nature, presenting natural processes, ecological fragilities, and anthropogenic impacts. Visitors were invited to engage through simple interactive gestures, influencing the projected scenes, symbolizing how human action can either protect or harm ecosystems. The project also introduced the theme of cultural biodiversity, emphasizing how the introduction of non-native species to Palermo is historically linked to the migration of cultural knowledge, myths, and traditions (UNESCO, 2001). This interplay between ecological and cultural heritage enriched the educational value of the installation, offering visitors a layered understanding of nature as a living archive of human-nature interactions. In terms of informal environmental education, *Anima Mundi* effectively raised awareness by embedding environmental content in an emotionally engaging and culturally significant experience. Its use of familiar urban nature—the botanical garden—and iconic plants helped connect environmental issues to a sense of place, especially for local audiences. However, its contribution to deeper knowledge was more evocative than structured. Ecological messages focused on emotional impact rather than on building a clear understanding of ecological processes, sustainability, or policies, leaving visitors without tools to deepen their learning afterward. The project successfully fostered pro-environmental attitudes, evoking curiosity and empathy through sensory immersion and storytelling. However, this attitudinal shift could have been reinforced if the planned hands-on workshops had not been canceled due to COVID-19. Opportunities for skill development were limited. Visitor interactions were symbolic rather than practical, offering little in terms of concrete environmental or civic skills. This reflects a common challenge with artistic installations, which prioritize emotional engagement over skill-building. Finally, the participatory dimension was weak. Visitors followed a pre-scripted experience without contributing content or co-creating knowledge, limiting their sense of agency in environmental action.

Across the four digital functionalities, *Anima Mundi* excelled in immersiveness, transforming the garden into an interactive stage. It simulated ecological processes in real time through projections and integrates ecological, cultural, and historical content—though this was curated by the project team, not enriched by users. Accessibility was high, requiring no personal devices or digital skills, and it reached a diverse audience, including many typically outside the reach of standard environmental education initiatives.

In conclusion, Anima Mundi shows how art, technology, and environmental education can converge in public space, fostering awareness and emotional connection. However, its potential to deepen knowledge, build skills, and promote participation remains limited. To expand its educational value, it would need structured learning activities, collective dialogue, and stronger links to ongoing urban greening efforts, transforming it from a temporary event into a lasting educational process.

Conclusions

This paper set out to investigate how digital technologies can support informal EE in urban contexts, addressing two main research questions: (i) which functionalities of digital technologies enhance informal EE in cities, and (ii) how these functionalities contribute to the achievement of key EE objectives, as defined by UNESCO & UNEP (1977, *op.cit.*).

The study's analysis showed that cities, as complex socio-ecological systems, play a key role in fostering informal environmental learning. Urban spaces, with their visible ecological challenges and opportunities, represent powerful educational settings where learning emerges through daily life, culture, and civic action. Digital technologies further enhance this potential, offering immersiveness, simulation, data integration, and accessibility, turning cities into dynamic learning arenas.

The study's review of Augmented Reality, Participatory Platforms, and Video mapping revealed distinct strengths and limits. Augmented Reality excels in immersion and simulating environmental processes in urban spaces, but its low accessibility—requiring apps, devices, and technical skills—limits spontaneous, wide-reaching learning. Participatory Platforms effectively integrate environmental data, citizen input, and collaborative decision-making, enhancing knowledge and participation, but their low immersiveness and digital literacy barriers restrict accessibility. Video mapping stands out as the most accessible and immersive in public spaces, turning urban facades into educational tools, though its impact on knowledge, skills, and participation remains weak when not explicitly designed for education.

The case studies presented here confirm this differentiated potential. Superbarrio demonstrates how gamified participatory platforms can turn environmental co-design into a learning experience, fostering awareness, knowledge, attitudes, skills, and participation through playful collaboration. Anima Mundi demonstrates how video mapping can spark emotional connection and curiosity about nature, though it offers little room for deeper learning or active participation.

Overall, the research shows that digital technologies contribute most to informal EE when they are part of broader cultural and environmental programs, linking artistic experiences, participatory processes, and real opportunities for action. Technologies alone do not drive transformative learning—they need to be framed within processes that foster critical thinking, dialogue, and long-term citizen engagement with urban ecological issues.

Future research should examine how digital experiences shape long-term ecological awareness and behavior, and how cities can integrate these tools into continuous learning ecosystems linking environmental education, cultural programs, and participatory governance. Hybrid approaches combining digital art, citizen science, and co-creation also deserve attention, particularly for their role in fostering collective learning and environmental stewardship during urban ecological transitions.

In conclusion, digital technologies can enhance informal environmental learning in cities, but their impact relies on moving from isolated events to ongoing, participatory, and culturally embedded learning processes—where technology supports, rather than replaces, critical reflection and collective action.

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