

Inclusive Interactions for Place-Belongingness: Lessons from Citizen Science

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Abstract

The active involvement of marginalized and vulnerable groups such as migrants and newly arrived refugees in the development of local communities has been part of many agendas across the EU and around the world. Despite the lessons gleaned from more than three decades of IUI research, there is still a shortage of systematic understanding and concrete guidance on how to design more socially inclusive and culturally sensitive interfaces targeted to these populations. In this paper, we argue that community-based citizen science approaches hold the potential to foster people-place bonds and inform the design of inclusive interactions since these initiatives are typically open to a wide audience regardless of race, ethnicity, gender, and education. From portable environmental monitoring devices to open databases providing place-related data about species observations and environmental threats, citizen scientists have a socially transformative and place-development potential that is often overlooked from an interaction design perspective. This research investigates this gap by examining digital interactions in citizen science through a systematic literature review addressing interaction possibilities for digitally enhanced place-belongingness. The results indicate three interaction themes within citizen science literature contributing to digitally enhanced sense of place-belongingness: place awareness and involvement, experience sharing, and collaboration encouragement. In addition, we found that the inclusivity goals in citizen science initiatives typically vary from urban and rural development to cultural purposes and environmental engagement and conservation. The interaction themes, along with the negative impacts of digital technologies, are discussed regarding their potential to inform technology design for place-belongingness in HCI.

Keywords

community supported citizen science, digital technologies, interaction design, people-place bonds, place-belongingness, social inclusion, vulnerable groups

1. Introduction

A sense of belonging to a geographical context, referred to as place-belongingness, can significantly impact one's well-being at both personal and societal levels [1, 2]. This highlights the importance of interventions and tools designed to enhance place-belongingness. Such efforts are particularly crucial for individuals at risk of exclusion, such as immigrants, refugees, and people with disabilities, in today's world, where place-belongingness is increasingly

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threatened by migration crises, isolated lifestyles, and the transformative effects of the communication revolution.

Place-belongingness is commonly defined as a sense of feeling at home in a specific place [1]. However, this positive emotional connection to a place is not a static phenomenon. Instead, it is intertwined with the dynamics of social and spatial inclusion, positioning it as an active process where individuals constantly navigate and negotiate their socio-spatial inclusion [2]. Consequently, enhancing this emotional connection necessitates solutions specifically tailored to its place-based, active nature, combined with its interconnection to the socio-spatial dynamics of inclusion.

Digital technologies are often integral to a wide range of solutions in the contemporary world. These technologies have demonstrated their effectiveness in supporting well-being [3], as well as in strengthening connections between people and places [4]. Although research (see e.g., [5-7]) provides evidence of the positive impact of digital technologies as a by-product in fostering place-belongingness, digital solutions explicitly designed to enhance place-belongingness remain rare.

Given the unique characteristics of place-belongingness, the search for effective solutions to foster it can draw inspiration from citizen science, which emphasizes inclusive and often place-based activities. In this context, digitally enabled citizen science activities that have the potential to enhance emotional connections between individuals and places provide insights for designing interactions to support place-belongingness. This study presents a systematic literature review to extract insights from citizen science to be utilized to inform digitally enhanced place-belongingness design.

The remainder of this paper is structured as follows. In Section 2, we begin by outlining the rationale for using citizen science activities as a source of inspiration for designing interactions that enhance place-belongingness. The third section details our method for conducting the literature review. Section 4 presents our findings, offering a range of activities that can inform the design of interactions aimed at fostering place-belongingness. We discuss these interactions and conclude with recommendations for future research.

2. Citizen Science as a Backdrop for Inclusiveness and Place-Belongingness

With the continual influx of digital environments able to support implicit but also explicit and actionable interactions that make part of our everyday life, citizen science platforms provide a unique infrastructure where enthusiasts can actively share experiences and actively build relationships within a community or place [8, 9]. These people-place bonds developed through the local engagement in citizen science activities like large flightless bird watching [10], marine-biodiversity awareness and conservation [11], and farmland biodiversity monitoring [12] provide a basis for motivating individuals to feel the particularities of each location they interact with during their citizen science activities, including the underlying geospatial, socio-cultural, and even historical accounts of each place [13]. At the same time, citizen scientists can act as “place-makers” [14] in the sense that they contribute to place (re)discovery around place-based social connections with implications for hyperlocal communities [15]. By monitoring natural parks, beaches, local lakes, or any other (un)protected areas like urban and peri-urban spaces, citizen scientists can have an inclusive role in these environments while

harnessing local community insights and resources [9, 16]. Besides the social capital that appears as a natural outcome of those participating in citizen science programs, the diversity of social and cultural contexts that are embedded in such digital technologies can make citizen science socially inclusive [17]. This is in line with the EU strategy for the inclusion of temporarily displaced people such as vulnerable migrants and/or cultural minority groups and refugees through citizen science [18]. The notion explored here is that volunteer participation in community-based citizen science projects happening in urban city and surrounding environments like schools, museums, and heritage sites can contribute implicitly to creating people-place bonds while integrating economically and socially vulnerable people as an altruistic approach that holds potential to incentivize citizen scientists to retain or even increase their participation levels in such endeavors.

Despite the manifested need recognized by the intelligent user interfaces (IUI) research community to foster the social inclusion of migrant children [19] and children with autism spectrum disorders [20], there is a lack of research on the intersectional space of citizen science and place-belongingness from a human-computer interaction (HCI)-centered viewpoint intended to design more inclusive interactions [21]. In line with this, we revisit the Hornbæk and Oulasvirta's [22] notion of interaction as a key concept in HCI that explicates events occurring between a user and a technology. This causal relationship can be explained by considering interaction as dialogue, transmission, tool use, optimal behavior, embodiment, experience, and control. By explicitly defining what interaction is, we can better account for the effects that design and technologies have on interaction. As a dialogue, interaction is defined as a cyclic process of communication and interpretation composed of stages and turns. Transmission considers interaction as transmission of information between technology and the user. The focus is not on communicative acts but in passing information contents over a channel. Thirdly, interaction as tool use considers interaction occurring via technology manipulated by users to make changes beyond the tool itself and as an extension of the self. As also described by Reeves and Beck [23] interaction as tool use indicates that the technologies and their use change us and how we act (through user interfaces). The concept of optimal behavior sees interaction as adaptive user behavior pursuing to maximize utility in user goals by mitigating task constraints, own capabilities, and the user interface. Embodiment considers interaction from the first-person view (c.f., tool use from the third-person view) as being and participating in the world emphasizing situatedness in using technologies. Interaction as experience is grounded in the understanding of human experience as the key factor in how interaction unfolds. Experiences are private, often momentarily, including evaluative feelings of the technology-interaction in question. Experiences also change in time and are affected by expectations and previous experiences, often affected by and directed towards the non-instrumental qualities instead of utility. Lastly, interaction as control considers interaction as minimizing errors against user goals and adapting behavior according to the interaction outputs [22]. In digitally mediated place-belongingness the quality of interactions with technologies can be evaluated and designed using key interaction concepts.

3. Method

This study employed the Cochrane gold-standard protocol [24] to perform a rapid review. While the methodologies for rapid reviews are still developing, their growing appeal in HCI

research stems from their ability to simplify and accelerate the systematic review process [25, 26]. This method provides a practical substitute for conventional systematic reviews, enabling the generation of thorough, reliable, and comprehensive findings even when time and resources are restricted [27]. Such reviews employ deliberate streamlining techniques, which may involve bypassing or condensing certain stages, yet they uphold the fundamental tenets of synthesizing knowledge, including setting precise goals, determining inclusion criteria, evaluating the credibility of data, and organizing results in a structured and logical way [28]. The PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was utilized to organize the review process and tackle the research question (RQ):

- RQ. How can digitally enabled citizen science inform interactions with digital technologies to enhance place-belongingness?

Answering this question can aid in developing effective solutions that inclusively improve the quality of life by fostering place-belongingness. To guide our approach, we aimed to identify studies in which digitally enabled citizen science activities contributed to strengthening people-place bonds.

3.1. Search Terms

Place-belongingness is a complex construct that overlaps with related ideas, such as place attachment and community belonging [14]. Similarly, citizen science encompasses diverse methodologies and approaches, often referred to interchangeably with terms like participatory science or crowdsourced science. Furthermore, digital technologies span a variety of tools, represented by varying terminology across literature. To comprehensively address RQ, it was essential to incorporate an extensive set of keywords in our review (see Figure 1).

("citizen science" OR "community science" OR "public science" OR "participatory science" OR "crowdsourced science" OR "collaborative science" OR "volunteer-based science" OR "amateur science") AND ("place-belongingness" OR "place belongingness" OR "place attachment" OR "place bonding" OR "place rootedness" OR "place connectedness" OR "place identity" OR "sense of place" OR "belonging in place" OR "sense of belonging" OR "social inclusion" OR "sense of inclusion" OR "social membership" OR "sense of community" OR "homing" OR "at homeness" OR "homemaking") AND ("digital technolog*" OR "digital tool" OR "digital solution" OR "digital media" OR "digitalization" OR "digital space" OR "information technolog*" OR "communication technolog*")

Figure 1. Search string used to identify potential studies.

3.2. Inclusion and Exclusion Criteria

The concepts of place-belongingness and citizen science are explored across multiple disciplines. Consequently, we utilized the Scopus database for our keyword search, as it offers comprehensive scope and reliable credibility. An initial exploration of article titles, abstracts, and keywords revealed a limited pool of materials capable of addressing the research question. As a result, the search was broadened to all fields, casting a wider net to ensure the identification of potential resources.

To ensure thoroughness, the identification process encompassed all years and subject areas. However, gray materials, such as books and book chapters, were deliberately excluded and our search was limited to papers published in journals and conferences. This restriction is especially vital for saving time during a rapid review process and guarantees that the selected material adheres to standards already validated by the scientific community. The identification process was further narrowed to include only papers that had reached their final stage of publication. Additionally, the analysis focused solely on papers written in English, as handling materials in other languages exceeded our resource limitations. The filtering options provided by Scopus were utilized to refine the material selection.

3.3. Screening Process and Eligibility Assessment

Titles, abstracts, and keywords of the identified papers underwent a screening process to eliminate those insufficiently addressing the research question. During this phase, details of excluded papers—such as title, author(s), publication year, publisher, access link, and exclusion rationale—were documented in an Excel sheet for future reference. The remaining papers were transferred to a new file for detailed examination. Full-text versions of these papers were retrieved and assessed for eligibility based on their relevance to the research question.

To streamline the review process, the quality of the papers was evaluated by confirming whether they had undergone double-blind peer review and leveraging the expertise of reviewers who conducted those assessments. The first author carried out the screening and eligibility evaluation, with other authors performing double checks to ensure the accuracy and reliability of both the process and the results. Figure 2 illustrates the PRISMA flowchart rigorously followed to achieve the final selection of eligible studies.

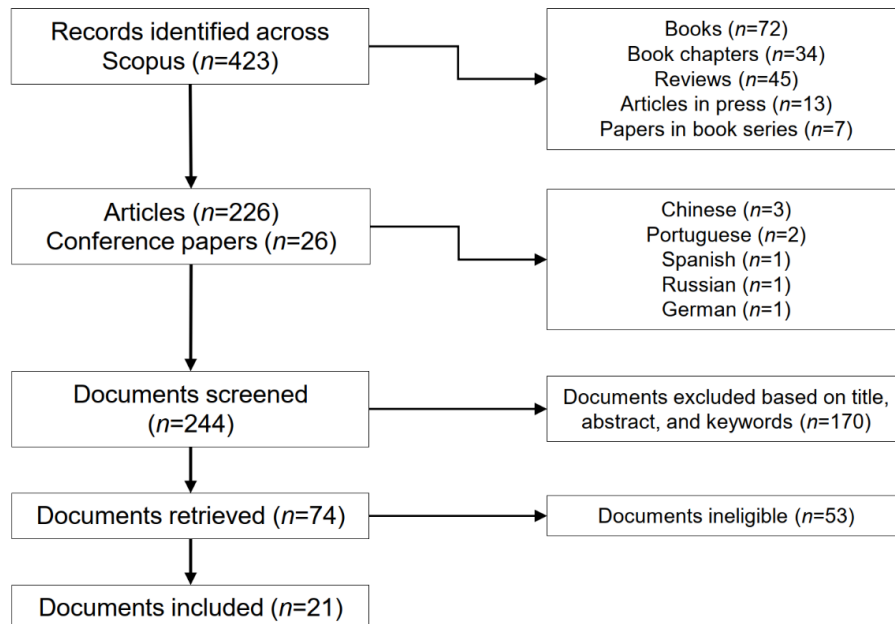


Figure 2. The number of documents screened and excluded at different stages of the review.

3.4. Data Analysis

Data analysis followed a six-step procedure: 1) familiarization with the articles by reading, re-reading, and outlining initial themes; 2) revision of the initial themes by systematically analyzing descriptive features of the interactions; 3) creation of the themes; 4) review of the themes; 5) re-revision of the themes to ensure descriptiveness; and 6) writing the results (i.e., descriptions of themes with corresponding articles) [29].

4. Findings

On December 16, 2024, the Scopus database search using specified keywords came to an end, identifying 21 papers suitable for data extraction (refer to Table 1). A significant portion of these studies appeared in journals and conference proceedings dedicated to research on the natural environment. Additionally, notable publication outlets included those focused on geography, sustainability, and fields such as computer and information science.

Digital technologies can facilitate the inclusivity that citizen science aims to achieve. Through our review, we identified the development of urban and rural areas as a key objective of this inclusivity. For instance, [30] utilized a mobile application to contextualize food access at the neighborhood level, contributing to improved well-being. [31] demonstrated how a digital platform could amplify marginalized voices and address urban challenges in Copenhagen. Digital technologies can significantly foster a sense of community [32] and promote the inclusion of diverse groups in tackling urban issues [33, 34], enhancing resilience [35], and facilitating the social and economic development of urban spaces [36-38]. Likewise, these tools offer valuable support for addressing challenges and promoting equitable and sustainable development across diverse contexts in rural areas [39, 40].

Inclusivity can also extend to environmental engagement and conservation. [41] underscore the role of digital technologies in increasing individuals' engagement with environmental issues. [42], [43] highlight the importance of these technologies, particularly during the COVID-19 lockdown. [44] emphasize the value of participatory digital tools in landscape conservation projects. Additionally, these tools enable researchers to employ participatory methods for scientific activities and understanding the factors and values essential for environmental conservation [45-48].

Furthermore, the inclusive digital approach to citizen science can serve cultural purposes. [49] utilize digital tools as an inclusive method for preserving refugees' memories of their homeland. Similarly, [50] highlights various participatory digital tools that can aid in envisioning and designing future music festivals.

Numerous reviewed studies emphasize the importance of including vulnerable groups in digital citizen science. Several specifically focus on underserved communities [30], rural populations [39], [40], ethnic minorities, individuals with disabilities, LGBTQ+ communities, refugees and expatriates [31, 49], and older adults [36].

Table 1.
List of included papers.

Reference	Journal/Conference	Inclusivity goal	Vulnerable groups
Afaneh et al. [30]	International Journal of Environmental Research and Public Health	Urban development	Yes
Arts et al. [42]	People and Nature	Environmental engagement	Not found
Birnbaum et al. [40]	Journal of Rural Studies	Rural development	Yes
Burgos-Thorsen et al. [31]	Visual Studies	Urban development	Yes
Collins and Welsh [35]	Area	Urban development	Yes
Curto-Millet and Canibano [34]	Journal of the Association for Information Systems	Urban development	Yes
De Meulenaere et al. [32]	Journal of Community Psychology	Urban development	Not found
Eanes et al. [44]	Journal of Coastal Conservation	Environmental conservation	Not found
Gudowsky et al. [36]	Futures	Urban Development	Yes
Hunter et al. [37]	Sustainability	Urban Development	Yes
Koukoulis and Koukopoulos [49]	Heritage	Cultural purpose	Yes
Mattijssen et al. [45]	Ecosystems and People	Environmental conservation	Not found
Misra et al. [46]	Journal of Environmental Management	Environmental conservation	Not found
Popescul et al. [33]	IEEE Access	Urban development	Yes
Radicchi et al. [38]	Noise Mapping	Urban development	Not found
Robertson et al. [50]	Event Management Information Systems	Cultural purpose	Not found
Roszczynska-Kurasinska and Wróblewska [48]	Sustainability	Environmental conservation	Yes
Turnbull et al. [43]	Transactions of the Institute of British Geographers	Environmental engagement	Yes
Verploegen et al. [47]	Conservation and Society	Environmental conservation	Yes
Webber et al. [41]	Conference on Human Factors in Computing Systems	Environmental engagement	Yes
Ye et al. [39]	International Journal of Information Management	Rural development	Yes

Some studies mention vulnerable groups without placing them at the center of their research. For example, [34] broadly examine the inclusion of underrepresented groups in digital participation platforms like Decide Madrid. Other studies explore the role of digital citizen science in capturing marginalized groups' lived experiences during lockdowns [35], fostering their civic engagement in smart cities [33], promoting their involvement in environmental initiatives [48], and amplifying their voices [37]. Webber and co-authors [41] call for incorporating indigenous perspectives into studies of human-nature relationships.

Furthermore, some works point out the demographic limitations of research and the exclusion of underrepresented groups [43, 47].

4.1. Fostering People-Place Bonds through Digitally Enabled Citizen Science

In this section, the interactions described in the included articles were analyzed using thematic analysis [29], resulting in three themes summarized in Table 2. The table also highlights the digital technologies that enable these interactions.

Table 2.

Digital interactions in place-based citizen science activities.

Interaction themes	Technologies	Example articles
Place awareness and involvement	Crowdsourced platforms, Digital maps, Drones, Games, Social media, Geolocated information systems	[30], [33], [38], [41], [43], [44], [45], [46], [47]
Experience sharing	Social media, Storytelling tools, Crowdsourcing platforms, Collective memory systems and digital archives, Geolocated information systems	[35], [40], [42], [44], [47], [49], [50], [52]
Collaboration encouragement	Social media, Augmented and virtual reality, Crowdsourcing platforms, Geolocated information systems	[31], [32], [34], [35], [36], [37], [39], [44], [48]

4.1.1. Place awareness and involvement

The first theme relates to digital interactions that have the potential to foster place-belongingness by enhancing place awareness and promoting place involvement. Digital technologies used in citizen science have proven to be powerful tools for enhancing awareness among participants, fostering deeper emotional connections to their surroundings. For instance, trail cameras, webcams, drones, and sensors for sound, light, water quality, and moisture, along with platforms such as iNaturalist, eBird, and Waarneming.nl, facilitate nature observation, enhancing users' attentiveness and deepening their sense of wonder and appreciation [33, 41, 43, 45, 47]. Google maps and many other instances of interactive maps can enhance place awareness by encouraging exploration and detailed observation, as highlighted by [41].

Discovery Tool is an example of digital apps inspiring participants to reflect deeply on different aspects of their surroundings in an urban context, leading to reinforced emotional ties and even motivating advocacy for community improvements [30]. Awareness and involvement with physical environments extend beyond visual elements to encompass aspects such as soundscapes, exemplified by applications like Hush City [38].

Digital technologies can inspire citizens to actively engage with and care for their surroundings, strengthening their emotional connections to their environments. Games like Pokémon Go can motivate people to visit green areas, creating opportunities for interaction with nature and fostering new relational values [45]. Many citizen science platforms create a cycle of engagement, where initial mediated interactions spark curiosity, reinforce sensory and emotional connections, and sustain continued involvement and long-term environmental

stewardship [41]. Crowdsourced platforms and real-time communication tools, such as those used in the Appalachian Trail project, enable participants to contribute to public conservation efforts. These activities not only build a sense of responsibility but also foster emotional bonds to the environment [46]. Similarly, Wisconsin Geotools platforms can inspire active engagement with landscapes while fostering a commitment to preserving natural and cultural heritage [44].

4.1.2. Experience sharing

The second interaction theme that can strengthen place-belongingness stems from the potential of digital technologies to facilitate the sharing of experiences and memories. Numerous reviewed studies highlight that digital technologies are instrumental in preserving and fostering personal and collective memories of places, allowing individuals to maintain emotional connections to their environments. Collective memory management system [49] can enable individuals, especially displaced populations such as refugees, to associate memories and stories with specific locations. These systems can strengthen emotional bonds to ancestral lands and cultural heritage, fostering a sense of belonging even in the absence of physical access.

Web 2.0 tools like social media and platforms such as Wisconsin Geotools allow participants to document and share their experiences of local landscapes through photos, videos, and notes [40, 44]. Platforms such as Waarneming.nl can provide digital archives for preserving records of biodiversity and environmental changes, producing comparable emotional results [47]. During the COVID-19 lockdown, wildlife spotting apps (e.g., iRecord) and other observation tools [35, 42] became critical for helping individuals not only reconnect with nearby nature but also share their observations. Moreover, mobile tools and social networking platforms have aided and pushed real-time narratives and storytelling processes [50].

4.1.3. Collaboration encouragement

The third interaction theme is inspired by the effective role of digital technologies in fostering collaboration. WeCountry platform, as highlighted by [39], offers avenues for collaboration across various aspects of rural daily life, fostering strong emotional connections to both places and the communities within them. Tools used in the Wisconsin Geotools project enable citizens to participate in eliciting landscape knowledge, supporting collaborative coastal landscape conservation efforts [44]. Collaboration in citizen science platforms fosters a sense of care for natural environments through community engagement [35]. Moreover, according to [48], these tools can promote critical thinking and problem-solving skills, encouraging citizen environmental participation.

In urban settings, while platforms that rely on individualism and disconnect citizens from social dynamics are insufficient in addressing problems [34], participatory digital tools such as crowdsourcing platforms, augmented reality applications, GIS tools, and smart city technologies encourage co-creation and collaboration, as seen in City Builder and the UB App projects [31, 36, 37]. These technologies enable citizens to actively engage in urban design and data sharing, fostering a sense of agency and pride in their local environments. Online Neighborhood Networks (ONNs) further exemplify how digital platforms bridge physical and

virtual spaces by encouraging the exchange of norms, values, and shared experiences, ultimately reinforcing community ties and collaboration [32].

4.2. Addressing Negative Impacts

According to the reviewed studies, the use of digital technologies can negatively affect human-place connections in at least three avenues, including: the disembodiment of experience, structural and digital divides, and a decline in motivation.

Digital tools can detach experience, identity, and interaction from the physical body, transforming tangible, place-based experiences into abstract or symbolic representations. For instance, some hikers, engrossed in constant technology use to document their journeys, inadvertently dilute their wilderness experience, diminishing the sense of immersion they seek in natural environments [46]. Several studies (e.g., [41, 42]) critique this disembodiment, arguing that it reduces the depth and richness of human-place interactions.

The effectiveness of citizen science platforms in fostering human-place connections depends heavily on whether these technologies are accessible to all participants. Those who struggle with digital literacy may experience a sense of alienation and isolation, weakening their emotional connection to their environment and community [36]. Resource constraints are also among main barriers that limit the extent to which diverse populations can employ digital technologies [48]. In addition, digital technologies can exacerbate social, political, gender, and other structural divides.

Digital technologies can inadvertently strip away the elements of surprise, challenge, and discovery that make individuals' motivation for physical interactions deeply resonant. Data visualizations and digital representations of nature contribute to this loss. They risk replacing the sense of exploration and curiosity that comes from direct, unmediated interactions with natural environments [41]. For instance, real-time navigation and information apps can reduce the sense of adventure and discovery that many hikers seek [46]. Such technologies can limit the spontaneity and unpredictability of outdoor exploration [44]. Moreover, idealized digital representations of nature often present sanitized or overly predictable views of the environment [42].

5. How do Citizen Science Activities Can Inform Interactions for Place-Belongingness

Our findings from the previous section provide insights for answering the RQ that guided our study on potential interactions that promote place-belongingness. Encouraging the awareness of a place and involvement with it can guide the creation of digital tools by incorporating elements of curiosity, gamification, and learning into interaction design. For instance, interactive maps with historical or cultural overlays can inspire individuals to explore and uncover a location's hidden features. Interaction with augmented layers can provide visualizations of potential improvements or exacerbations [7], inspiring users to get involved in a place and contribute to tangible changes. Gamified interaction and access to educational resources (e.g., [45]), particularly when integrated with mixed reality experiences, can motivate users to actively explore local knowledge while promoting sustained engagement with a place.

Creating opportunities for users to document, share, and celebrate their connections to a place serves as another pathway for designing interactions for place-belongingness. Digital

platforms can incorporate features that enable users to share photos, audios, videos, and written narratives, offering tools to highlight unique place experiences and connections through storytelling [53]. By integrating options to archive and revisit memories, such interactions allow users to reconnect with the past, deepening their emotional ties to a place over time. Furthermore, augmented and virtual reality-based interaction (e.g., [7]) can be used to recreate significant past moments, immersing users in the collective heritage and enriching their sense of belonging to the place.

The design of interactions that enhance place-belongingness can draw inspiration from features that promote collaboration. Digital tools can be designed to foster group activities, such as collaborative art projects, where participants work together to improve their environment [54]. Features like discussion forums and event planning tools can facilitate communication and coordination among participants. By creating spaces where individuals can share their knowledge, skills, and resources, digital technologies can empower underrepresented groups and amplify diverse voices, contributing to inclusivity and belonging within a place. Additionally, gamified elements can motivate individuals to participate in friendly competitions and interactive challenges [55].

Addressing negative impacts can mitigate challenges that hinder individuals' connections to their surroundings. To counteract disembodiment, digital technologies can emphasize the unique physical significance of a place. Gamification elements offer effective solutions, while other tools, such as location-based narratives, can also enhance place-based engagement. Personalization features that tailor content to the user's location, history, or preferences can also reinforce a sense of place [56]. Addressing inequalities and divides requires inclusive design approaches, such as providing multilingual interfaces, ensuring accessibility for users with disabilities, and offering offline or low-bandwidth functionalities to reach underconnected communities [51]. To combat loss of motivation, platforms can integrate dynamic, evolving content that keeps users interested. Discussion forums or collaborative features can also help sustain long-term involvement.

6. Conclusion

We conducted a systematic literature review of digital interactions in citizen science to extract interaction possibilities for digitally enhanced place-belongingness. The results suggest that key features for designing inclusive interactions to enhance place-belongingness include curiosity-driven exploration, gamification, learning opportunities, mixed reality experiences, multimedia sharing and archiving, online co-working and planning spaces, discussion forums, as well as personalization and flexible accessibility options.

The three identified themes of interactions within citizen science (i.e., place awareness and involvement, experience sharing, and collaboration encouragement) can contribute to the design of interactions for digitally enhanced sense of place-belongingness. Moreover, we emphasized addressing the negative impacts of digital technologies on the human-place emotional connection, particularly issues such as the disembodiment of experience, structural and digital divides, and diminished motivation.

Future studies can empirically examine the effectiveness of the identified themes. Developing a validated measurement tool that can assess place-belongingness across its

various dimensions is crucial for evaluating the effectiveness of digitally enhanced place-belongingness, particularly among vulnerable groups, such as immigrants and refugees.

Further studies are needed to explore the intersection between interaction themes and the negative effects of digital technologies. For example, future research could investigate how to enhance place awareness and, by extension, place-belongingness through highlighting secure locations on a digital map, without unintentionally stigmatizing other areas.

Although digital technologies specifically designed to enhance place-belongingness are rare, the identified interaction themes can provide a solid foundation for developing innovative technologies in this area. Another research direction is to transform the knowledge obtained from the review into design guidelines for digitally enhanced sense of place-belongingness.

Declaration of Generative AI

The authors have not employed any Generative AI tools.

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