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Augmented reality as a participation tool for youth in urban planning processes: Case study in Oslo, Norway

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Augmented reality (AR) allows objects to be digitally simulated in the real world through smartphones, tablets, and headsets. While there are interesting AR technology case studies in participatory urban planning, this type of research has yet to be conducted within a real-life municipal planning scenario. Following the UN Habitat recommendation that further studies in AR as a participatory tool seek to integrate planning with real citizens, we studied the use of AR for the Oslo Trees plan in Norway. The case study consists of field work with AR between 2020 and 2021 over five weeks, with five different groups of youth participants from eight different districts of Oslo, who were tasked with planning a portion of Oslo's 100,000 new trees. We document how these youths used AR in films, images, drawings, interviews, screen recordings, and recorded presentations. We find that AR is a highly intuitive tool for these youth user groups in design and planning and how the AR schemes impacted the final design of the plan. The use of AR aided users' ability to generate their own planning proposals on site at scale; nearly all participants increased their understanding of participation, urban planning, architecture, and design in the workshops. In addition, the youths experienced an increased sense of confidence in displaying their design intentions and appreciated being given control of the planning process. However, we also found that location tracking and positioning in AR is imprecise and often "buggy" in the current state of the technology, causing irritation among users. Furthermore, despite the high degree of control afforded to users through AR, experts were still needed to verify which tree proposals were viable, offering important insights into how AR could be designed in the future. We conclude with a discussion on opportunities and barriers for the implementation of AR in participatory urban planning, pointing to the need for a more coordinated and holistic approach to both AR technology development and planning policy if the technology is to be developed further for participatory urban planning.

KEYWORDS

augmented reality, mixed reality, smart city, user participation, urban planning, participatory planning, interaction design

1 Introduction

Urbanization and digitization are impactful contemporary trends. A growing number of people—at least 55% of the world's population—now live in urban areas (World Bank, 2022); similarly, at least 60% of the world is now connected to the internet (Kemp, 2021). The expansion of urban land consumption outpaces population growth by as much as 50%, which is expected to add 1.2 million km^2 of new urban built-up area to the world in the next three decades, putting pressure on land and natural resources, and often resulting in undesirable outcomes (World Economic Forum, 2022). At the same time, due to the internet, the widespread use of smartphones, and the omnipresence of connected objects, citizens are better informed on what is occurring around them and are now expecting to participate in the development of their surroundings (Hasler et al., 2017).

The speed and scale of urbanization requires local governments to meet accelerated demands for services, infrastructure, housing, and public space, which also creates pressure to address environmental, social, and economic challenges for cities. With the expansion of ICTs in urban areas, the growing field of smart-city research has sought to build new knowledge on how digitization trends influence governance (Townsend, 2013; Landry, 2016). There is a strong belief that, with the help of digital tools, involved parties can be assisted in creating a shared urban vision and increasing the satisfaction of users of redesigned areas (Jutraz and Zupancic, 2015). International bodies such as UN-Habitat and Ericsson et al. (2019) have focused on how frontier technologies such as augmented reality (AR), when used for public participation, citizen engagement, and inclusive urban planning, can help bridge the gap between policymakers and residents to meet these challenges.

Urban planning is the discipline that attempts to manage and determine competing uses for land (Cullingworth and Nadin, 2002). The first urban planner and political philosopher in the European tradition, Hippodamus of Miletus, laid the foundation for the zoning and planning of land and the corresponding legal structure pertaining to citizens' use of such land, based on their class (Politics, Aristotle, ca. 350 B.C.E./1905). In the postwar period in the West, antagonism between the competing desires of master planners and local communities led Jacobs (1961) to attribute the perceived failure of urban planning to a lack of citizen empowerment in cities. Following this development, methodologies for increasing citizen participation were developed, such as the Arnstein (1969) Ladder of Participation, which lays out a sequence of steps which are meant to elevate citizen participation from manipulation (i.e., non-participation) to citizen control (i.e., citizen power). This ladder was later enacted into urban planning policy in several countries, including Norway.

Since these early developments in the postwar period, it has become more widely accepted that citizens should have more say in shaping local areas. The proposed benefits of participation in planning and design include increasing user satisfaction, creating realistic expectations of outcomes, and building trust; these also allow planners and designers to access community expertise and local knowledge, thus assuring better plans and designs (Al-Kodmany, 1999). Participatory urban planning is now considered an important aspect of the development of local democracy (Ertiö, 2015) and is reflected in the UN Sustainable Development Goals (SDGs) and the UN New Urban Agenda, which now positions participatory urban planning and inclusive public space as top priorities in cities and human settlements (UN Habitat and Ericsson et al., 2019). For example, the target indicator for SDG Goal 11 to make cities and human settlements inclusive, safe, resilient, and sustainable target 11.3 is articulated thus:

> "By 2030, enhance inclusive and sustainable urbanization and capacities for participatory, integrated, and sustainable human settlement planning and management in all countries."

In parallel with the development of participatory methodology in planning, there has also been an increased focus on youth participation. In 1985, the UN celebrated the first International Year of Youth, adopting the World Program of Action for Youth, and set a policy framework and guidelines for national action and international support to improve the situation of young people. In the wake of these guidelines, a revised *Plan and Building Act* in Norway required all municipalities to consider children and young people as full citizens, with rights to participate in local planning processes (Bygdås and Hagen, 2022). Through the formalization of the UN Convention on the Rights of the Child in 1989—ratified by Norway in 1991 and incorporated into Norwegian law in 2003 (Scheie, 2005)—children became recognized as competent actors with participation rights (Ursin, 2019). This provides some of the legal background to understanding the case study at hand and why a Norwegian municipality may be required to involve youth participation in an urban planning process.

Despite increased focus on participation, there have been difficulties in implementing participation theory and methodology in the real world. The translation of the democratic principles of participation in urban planning into established political and professional practices has been difficult to achieve or has remained low (Holman and Rydin, 2013). There are various factors affecting this, including rigid language (Conroy and Evans-Cowley, 2006), outdated "non-digital" methods (Evans-Cowley and Hollander, 2010), a lack of or over-complex forms of dialogue (Jutraz and Zupancic, 2015), the extent of costs, insufficient motivation among citizens (Townsend, 2013), and, in the youth and children context, exclusion from planning processes due to the rigidity of the planning process, neoliberal influences, and planners' lack of competence (Cele and Van der Burgt, 2015). Despite these difficulties, it is argued that participation still enables a better acceptance of urban planning policies and projects (Evans-Cowley and Hollander, 2010)—an argument which has likely sustained motivation for participation in planning.

As mentioned, a proposed method to fix the gap between theory and practice has been trends within digitization and so-called smart cities. With the rise of the internet and ICTs, it was speculated by King et al. (1989) that new forms of visualization could create a common planning language across technical and non-technical audiences. Advances in computer technology were seen to have the capacity to change and enhance the way the public interacts with design through visualization tools (Al-Kodmany, 1999). With the widespread adoption of smartphones, the use of mobile technologies to engage with citizens has gained interest among researchers, policymakers, and activists (Ertiö, 2015). This aligns with citizens' current expectations about having access to more detailed information on their city and influencing aspects of city planning, management, and development (Pokric et al., 2014). Embracing digital technologies in participatory planning is thus seen as a means by which citizens can more readily understand planning and raise awareness of the opportunities for involvement. It helps remove barriers to citizen engagement in the planning process (Wilson et al., 2017). This mirrors the call of the UN-Habitat and Ericsson et al. (2019) for member states to use information and digital technology to make urban planning more accessible to citizens and to engage them throughout the design process.

In the Scandinavian and Norwegian context, Bygdås and Hagen (2022) find that several studies also argue that technology can be a driving force for making participation among youth more engaging and effective. The use of digital tools such as Barnetråkk, Minecraft, and VR to increase youth engagement has been documented through case studies in Norwegian municipalities such as Stavanger (ibid). A 2010 study that investigated participation in the planning process in four selected cases in Oslo municipality (Schmidt et al., 2011) recommended, to a far greater extent, "use [of] the internet and new methods for 3D visualizations" in participation.

FIGURE 1
Youth participant places trees on site in Oslo through AR.

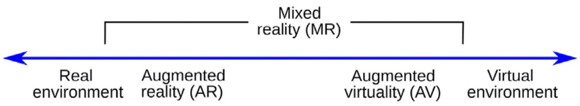

FIGURE 2
Reality–virtuality continuum. Reproduced under CC-BY-4.0, Freeman, R (2021).

Within the Nordic region, AR has been seen as a promising technology which is suitable for conveying complicated spatial forms in urban planning in an easy-to-understand way (Ausland, 2019). While AR is viewed as a technology that can be used in the early phase of planning processes, where the opportunities to contribute are greater, Ausland (2019) also pointed out that this technology can be problematic, in that it can be used to produce "glossy images" to seduce and reduce resistance. Bygdås and Hagen (2022) point out that, currently, AR is still a technology in its infancy, and that there are few or no studies to show that technology has left its mark on youth participation in Norwegian municipalities. Therefore, this study is probably the first of its kind to use AR in real youth participation in a Norwegian planning procedure (see Figure 1).

2 Materials and methods

2.1 Augmented reality in participatory planning

Mixed reality (MR) is a technology that enables visual experiences where physical environments and digital information coexist and interact (Barfield, 2017). A subset of mixed reality, augmented reality (AR), focuses on application within the real environment (Milgram and Kishino, 1994; Figure 2). The technology has its roots in the cyberculture of the 1960s, in which Englebart (1963) foresaw the future of cybernetics as an interactive process, involving computer-controlled changing images controlled by humans through interactive input devices. Sutherland (1965) proposed that a computer-based, multi-sensory, interactive simulated world could "look real, feel real, and act real." Decades later, Brooks (1986, 1990) made a case for interactive computer graphic simulations, including interactive 3D graphical simulations to represent the interior of buildings; the authors built a see-through HMD for various applications (Brooks, 1990). Later developments by Azuma (1997) focused on AR applications which could enable users to "walk" around large environments, even outdoors, which required making the equipment self-contained and portable. This could be seen today as an early version of what would become smartphone AR.

In the early 2000s, researchers began looking into manners in which AR could allow digital objects to be integrated into the urban environment, and importantly, to allow users to study digital proposals in a real-world setting. Following Billinghurst and Kato's (2003) development of interfaces for face-to-face and remote collaboration, Kato et. al. (2003) pointed to AR in urban planning as a potential breakthrough in how we interact with the built environment "because in city planning it is very important to arrange the layout of 3D objects such as buildings or trees and to see the relationship among them". Their team's groundbreaking work built a prototype which enabled users to consider city plans in AR and manipulate 3D structures that were displayed as virtual objects in a laboratory sandbox (Figures 3A–C). Note in Figure 3C that, in this study, we also see the use of tree planting in AR: Kato et. al. (2003) found the use of trees in AR urban planning to be a realistic future scenario. However, the ability to scale the AR technology from a prototype to large-scale consumer technology was then still many years away, and the trees were still in scale models rather than placed in the real world.

A recent critical breakthrough in AR, which allowed for this type of case study to be considered, has been the implementation of AR within everyday smartphones, thus becoming a ubiquitous

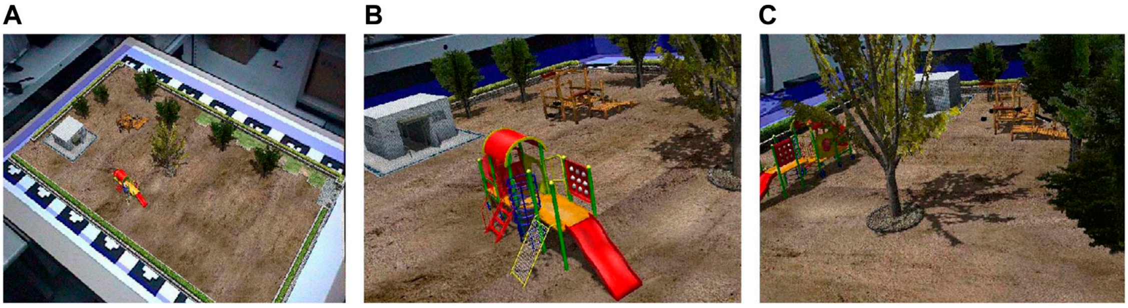

FIGURE 3
Panels **(A–C)**. A tabletop AR urban planning prototype developed by Kato et. al. (2003). Reproduced from Kato et. al. (2003), with permission from Institute of Electrical and Electronics Engineer.

consumer technology available to billions of users. The use of AR in smartphones was important because it made it possible to track a user outdoors with high enough accuracy to begin on-site experiments with AR in urban environments. In 2017, a prototype was released by NorKart and the Norwegian Mapping Authority called "BorderGO" (Figure 4) that depicted property boundaries in central Oslo transposed onto the real world in real time through the Google Tango smartphone system. However, Google Tango was discontinued not long after this prototype was released. Shortly thereafter, Apple announced its support of advanced AR in its premium smartphones and tablets with its A11 bionic neural engine and Apple's ARKit (Apple, 2017). Around this time, Berck (2017) presented several ways in which smartphone AR could potentially affect community and place-making efforts by demonstrating concepts for AR in urban planning situations (Figure 5). A 2018 prototype was demonstrated by ARUP and Dan Hill (Figure 6) that depicted how users could interact on-site with planning proposals through AR with a tablet; however, this prototype was not a functioning AR app but the use of wireframes in film-editing software.

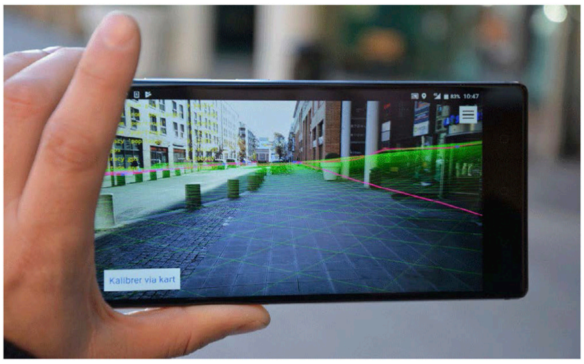

FIGURE 4
The BorderGO prototype developed by the Norwegian Mapping Authority. Available at https://github.com/kartverket/BorderGo. Published with permission.

The first real working prototypes for AR in participatory urban planning on site were documented in a collaboration between UN Habitat and technology developer Ericsson in 2018–2019, looking at how MR could be used to crowdsource urban planning in response to the UN SDG 11 Goals (UN Habitat and Ericsson et al., 2019). The report demonstrated the use of smartphones and a local Wi-Fi hub to conduct free-form scenario planning with youth in Johannesburg, South Africa, using Minecraft. The report found that MR held tremendous potential for real-time digital visualizations, both at the street and neighborhood level and for the overall urban skyline and city grid. According to the report, MR pulled users into the process of design and strengthened the long-term viability and buy-in of urban projects (ibid). Importantly,

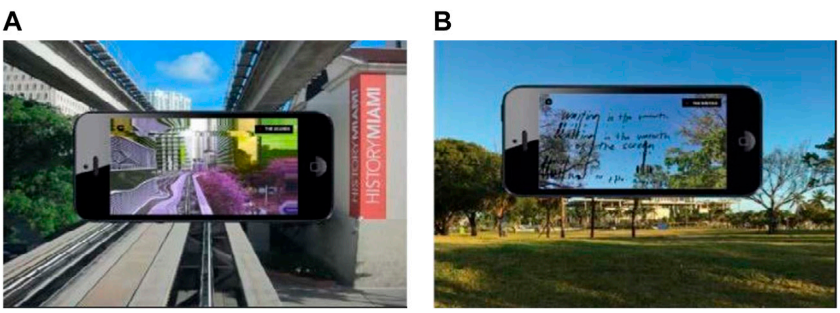

FIGURE 5
Berck (2017) which presents a number of ways that AR can affect urban planning, here the work of Depena (2016). Reproduced with permission from Depena (2016), https://ivandepena.com/work/lapse/.

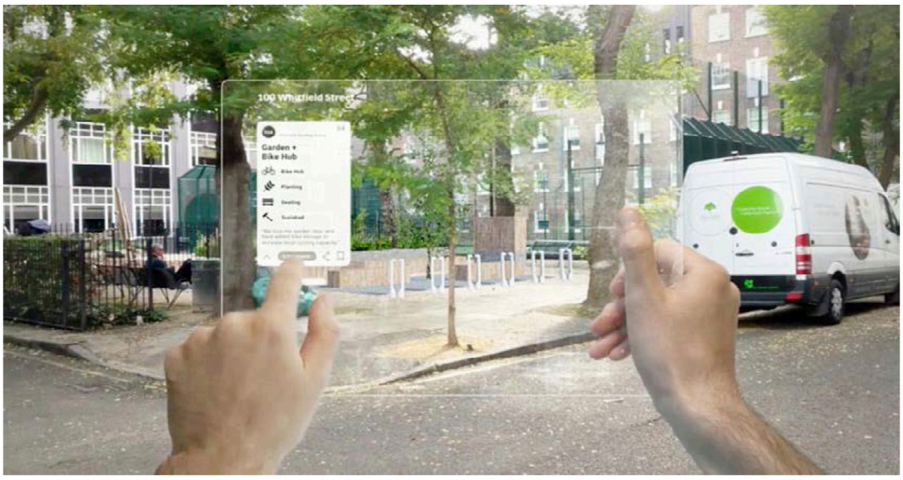

FIGURE 6
The City Planning Prototype made by ARUP / Dan Hill (2018) depicts how users could interact with planning proposals on site through AR. Reproduced with permission from Hill, Dan, "Augmented Planning Notice" Dec 13, 2022, Youtube Video, 1:00. Url: https://www.youtube.com/watch?v=zrJkUht9ywl&ab_channel=DanHill.

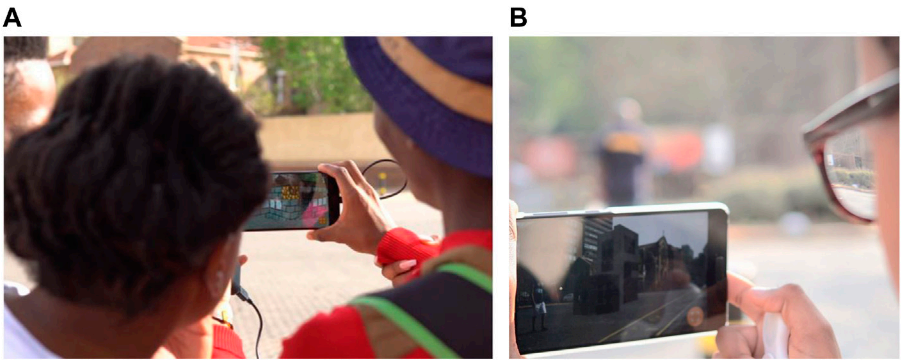

FIGURE 7
Panel **(A, B)**. Ericsson and UN-Habitat report: "Mixed reality for public participation in urban and public space design: Towards a new way of crowdsourcing more inclusive smart cities". Panel **(A)**: (Left) Participants in a workshop view their mindcraft designs in AR. Panel **(B)**: (Right) The mobile phone view in Minecraft. Reproduced from UN Habitat and Ericsson et al. (2019), with permission from UN Habitat and Ericsson.

while this project allowed users to sketch their own fantasies through a computer and import them into AR (Figures 7A, B), we also noticed that the technology was built within a Minecraft gaming system and thus could be more like a game than an actual urban planning scheme. This further fuelled our desire to test an actual planning scenario rather than a game.

As noted in the introduction, while the use of AR in planning shows some degree of promise, the technology is still in its infancy and there is currently a lack of actual integrated cases in municipalities (Bygdås and Hagen, 2022). The UN Habitat and Ericsson study noted the need for more pilots and iterative improvements of AR technology and how it is used for participation. The authors recommended that future studies be linked more clearly with the planning process of local governments to ensure that AR is deployed exclusively and effectively. The authors additionally stated that, in order for AR platforms to be useful for planning participation, local authorities must also identify and legitimize real-world use of the platform as useful for planners (UN Habitat and Ericsson et al., 2019). We also noted that most of the case study works, such as Berck (2017) and the ARUP and Dan Hill prototypes, were hypothetical without actual AR hardware and software or actual users, but were conducted using techniques such as video editing to produce wireframes and prototypes. This raised questions for the research team about whether AR could work as suggested by preceding cases and what bugs or technical limitations in AR technology may exist.

2.2 Using augmented reality in participatory planning: Background of Oslo, Norway

Having explained the background of participation in urban planning and the state of the literature on the use of MR in urban planning, we will now explain the local context leading to the case. The city of Oslo, Norway, has for several years been among the fastest growing cities in Europe and is experiencing high pressure regarding both growth and sustainability goals from its citizenry, creating the need for ambitious development projects. In 2019, a coalition government with a focus on green policies won city elections and initiated a series of new urban planning and development projects. Among these were the "Car Free City Life" plan and the Oslo Trees project. Oslo Trees has the goal of planting 100,000 new trees around the city by 2030 and for much of this work to be conducted by citizen participation. The planning of the project was then initiated by the City Council for Urban Development within a newly established department within the Planning and Building Agency known as ByKuben—Center for Urban Ecology. As part of the Oslo Trees project, ByKuben has sought to establish new types of partnerships to perform research and concept studies. One of the first steps was to engage youth groups from around Oslo through summer employment in Oslo Trees.

The current case study was initiated when ByKuben and Oslo municipality approached the research team in the fall of 2019 during the Creative Technologies research course at AHO—the Oslo School of Architecture and Design—which is part of an ongoing PhD project on the use of AR/VR in urban planning and design. ByKuben asked the research team if we had ideas for creative applications for user participation in the Oslo Trees project, with a particular focus on their youth user group. Our research at the time was focused on how digital technologies and media—particularly AR/VR—could enable new ways of designing urban services and positively affect issues of urban livability, sustainability, design, and the governance of cities and urban space but not particularly on youth (Martinussen et al., 2019). Oslo Trees was, therefore, a good fit for our research objectives, particularly since urban digital services combine data, infrastructure, and people in ways that serve commercial and/or civic purposes in the city. Understanding how the municipality could use AR to solve their needs was thus directly relevant to both parties.

What separates this case from earlier cases is the desire to include youth in participation and to investigate the use of AR within this context. As mentioned in the introduction, Norway has had a focus on increased municipal responsibility in facilitating youth participation in planning (Bygdås and Hagen, 2022). As the Oslo Trees project is run by the Oslo planning authority, the municipality thus has a duty through the *Planning and Building Act* to ensure that the requirement to facilitate participation is met. As a general principle, participation is anchored in the purpose section of this legislation and requires that those who submit plans include a proposal on facilitating participation, and the municipality must ensure that such participation can occur. Additionally, the law states that the necessary transparency, predictability, and participation are essential elements in the planning and construction process.

As also mentioned in the introduction, the most recent version of the Norwegian *Planning and Building Law* describes the legal requirement for municipal and state bodies to provide public participation studies through the various stages of planning (Ministry of Municipal Affairs and Modernization, 2014). The Norwegian government's 2014 report on youth participation recommended the greater inclusion of youth in urban planning, with a procedural analysis of nine different municipalities in Norway, in line with the UN requirements. Article 12 of the *UN Convention on the Rights of the Child* requires parties to ensure that children who are capable of forming their own views are assured of the right to express those views freely in all matters affecting them and that their views be taken into consideration; this is important because youth are seldom informed of what has happened after they provided their opinions or knowledge (Hagen and Andersen, 2021). This legal precedent forms the policy basis for Norway's Department of Family, Youth, and Child Affairs and is detailed in their handbook for youth participation (Barneombudet, 2018). It is therefore worth noting these legal requirements when considering how this case study was facilitated and structured.

2.3 Methods

The methodology for the study was determined in response to the goal of studying the use of AR as a participatory tool for youth in a real-life urban planning scheme and, second, in studying how AR influences the learning outcomes of youth. As mentioned, AR technology is still in its infancy and there is little data on youth experience of AR in an urban planning scheme. As designers, we hope to find ways to design high-quality interactive products and services at the intersection of urbanization and digitization. Therefore, we wanted to study the interactions between youth and AR, and between youth and the participatory urban planning scheme in question, and even urban planning more generally. Here, interaction design can provide various methods for exposing problems and design opportunities and find crucial information to use in the design process of both technologies and services. Hence, interaction design should serve both to analyze interactions and to design new ones which are preferably more user-friendly. In addition, our disciplinary background and research focus within the research project AHO—including a cross-disciplinary focus across technology development, architecture, planning, and interaction design—informed the chosen methodology of the study.

As we had the goal of studying youth user experience from the point of view of interaction design and AR development, various user research methods from interaction design and user research were employed to study the young users, especially observations of their interaction with AR. Additionally, qualitative interviews were used to help understand user needs and identify any problems that they may experience with the AR tools. Second, from the point of view of urban planning and architecture, we needed to use methods that could understand the youth users' experience of being embedded within an urban planning scheme as a participant, such as observations and semi-structured interviews during the process and, additionally, group interviews with the participants and semi-structured interviews with experts during the process.

As we would be doing field work around the city in the participation workshops, we knew that in-person, in-context observation would help us understand how users live in their own environments and contexts. User observation thus meant spending time with users and recording observations of their behavior with the AR product as they use it during the participation scheme. Due to the size of groups and the need to assess the data both during and after the participation workshops, we decided to observe the youth while performing the workshop

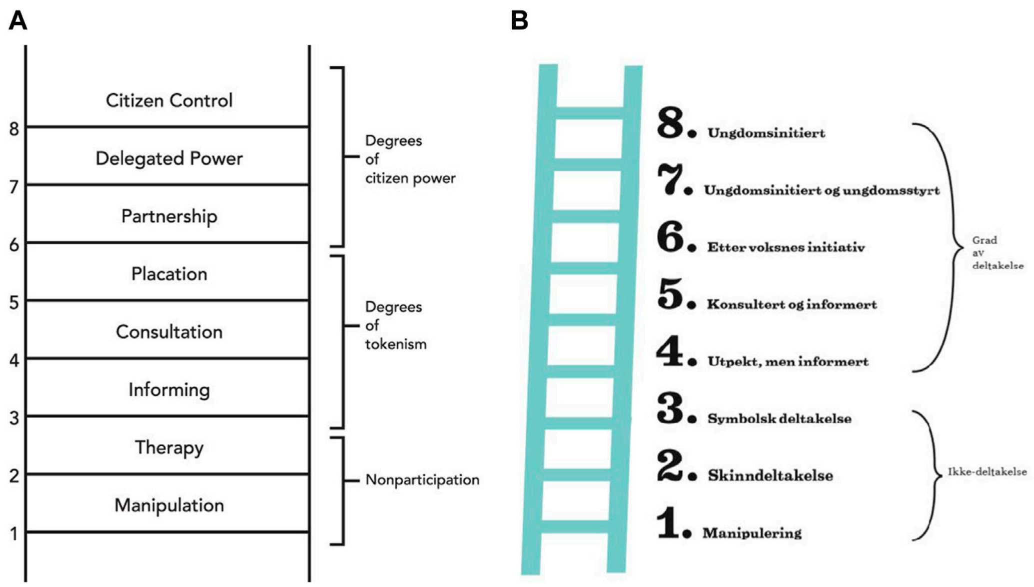

FIGURE 8
Panel **(A, B)**. Panel **(A)** (Left): Arnstein's Ladder of Participation (Arnstein, 1969) with permission from Taylor and Francis. Panel **(B)** (Right) Norwegian Department and Family and Child's Affairs version of the Ladder for Children And Youth Participation. With permission from Barneombudet (2018).

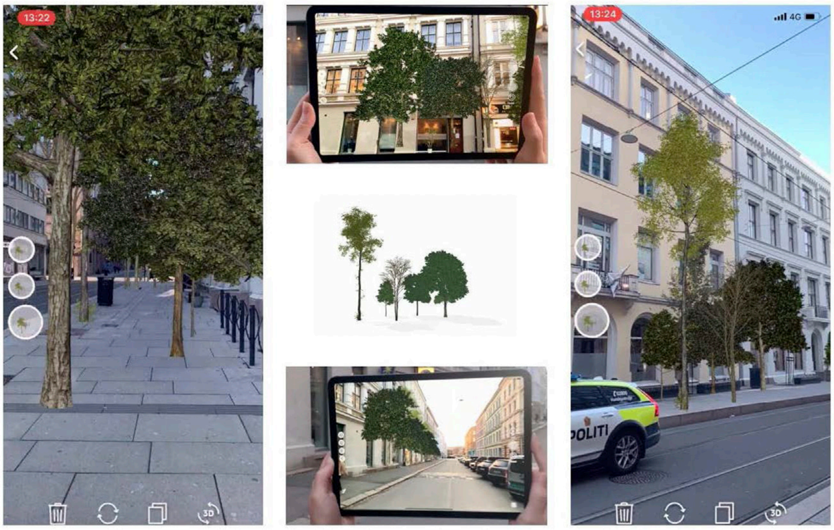

FIGURE 9
The original proposal made for Oslo Municipality.

tasks and also to take field notes, as well as making films and images—both by ourselves recording users, and, importantly, by recording the screens of the users. We therefore assembled a large research team of three to four for this case study who could follow the user group during the entire study and record field notes, observations by film and images, and use methods that allowed user interactions in AR to be screen-recorded during the participatory planning sessions and analyzed afterward. Importantly, this screen-recorded data needed to be anonymized, which was done by creating fake accounts with the AR apps and hardware and using the university's cloud data management system rather than asking the youth to provide personal accounts or any personal storage.

While observation could provide insight into how AR was being used as a participatory tool, our assumption was that we needed more qualitative insights into the learning outcomes of the youth themselves. Interviewing the groups of youth presented a challenge because, being underage, the participants were legally protected from sharing personal data. We therefore employed a range of

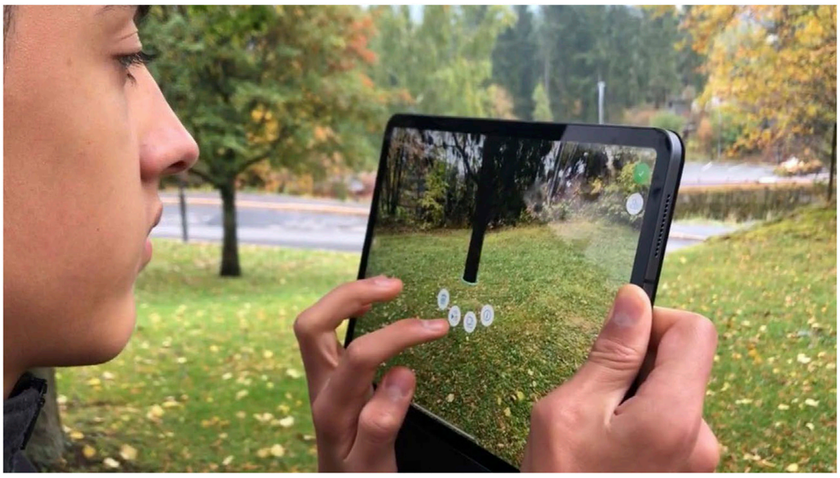

FIGURE 10
Image depicting youth user during workshop.

group interviews with the youths at the start and end of the workshops (Supplementary Tables S1–S4) and anonymized semi-structured interviews with the youths during the field work (Supplementary Tables S5, S6) as well as the expert interviews with their appointed guardians from the municipality (Supplementary Table S7) who could provide expert insight because they followed the youths for an extended time both before and after the workshop. These youth guardians, being appointed by the municipality, also were seen to have expert competence in understanding the everyday lives of the youth that we, as outside researchers, were likely to lack.

Finally, as the case was integrated within Norway's municipal legal requirements for facilitating participation among youth, we decided that the case study also needed to utilize a method to help determine its level of participation. We therefore decided not only to follow the abovementioned Ladder of Participation (Arnstein, 1969; Figure 8A) as mandated but also attempt to use the ladder as an analytical method to help classify to which level of citizen's involvement the AR tool was facilitating. We found that Norway's Directorate for Children, Youth, and Family Affairs (Bufdir) recommended their own Ladder for Youth Participation (2012, Figure 8B), which particularly focused on youth participation. We also took note of recent international studies, including Kara (2007), which found that the ladder model is a valuable tool for measuring whether a given project or institutional setting serves the interest of young people. Similarly, Cardullo and Kitchin (2019) and Hasler et al. (2017) served as importance references as they utilized different adaptations of Arnstein's (1969) ladder to measure participation in an urban planning study.

3 Results

3.1 Workshops, 2020–2021

Following Yin's (2013) multiple case study model, this case was one of several performed over 2018–2022 on the topic of extended reality (XR), including mixed (MR), virtual (VR), and augmented (AR) realities in urban planning and design. For this case, following our initial interactions with Oslo municipality and with ByKuben, an AR prototype was designed to test how AR could be used for youth participation in urban planning (Figure 9). This prototype utilized a mix of ARkit from Apple, a custom piece of software in Unity titled Udaru (User-driven Augmented Reality Urbanism), the Augment software package, and elements from iScape, an AR landscape app. This prototype demonstrated to the municipality how trees could be digitally planned for a street setting in urban Oslo.

After a period of prototypes, we agreed upon the case study's format, tools, and methods; following organizational meetings and planning over several months, the case study was executed as five separate workshops, each over a 1-week period in August 2020. Following review and feedback for the 2020 workshops, they continued in 2021. Each workshop consisted of a different group of youths from a dedicated city district from a wide range of locations in the city. The groups of youths ranged from 9 to 18 individuals. Depending on the size of the group, each youth participant (or partners of two) was given an iPad Pro for the duration of the workshop. Importantly, to preserve anonymity, the iPads were given an anonymous username and data were collected from each iPad rather than identifying any of the youths by name. Participants were also given a safety vest with the research team logo and a guidebook for the workshops with a calendar (Figure 10). These aspects became important in order to create group structure and coherence, provide safety in heavily trafficked areas, and display the research intentions to the public.

Participation workshops must be voluntary, and participants must be given information about the task and comply by participating after they have understood the task (Barneombudet, 2018). Hence, the first component of each workshop consisted of an introduction to the case study and to the task at hand. All participants participated voluntarily except for two participants in Workshop 4 who declined to participate because they were expecting physical tree planning work. These participants were allocated alternative tasks of planting actual physical trees. Following introductions to the task, participants were asked to practice using the AR application and try out planting trees. They were given a controlled site at the Oslo School

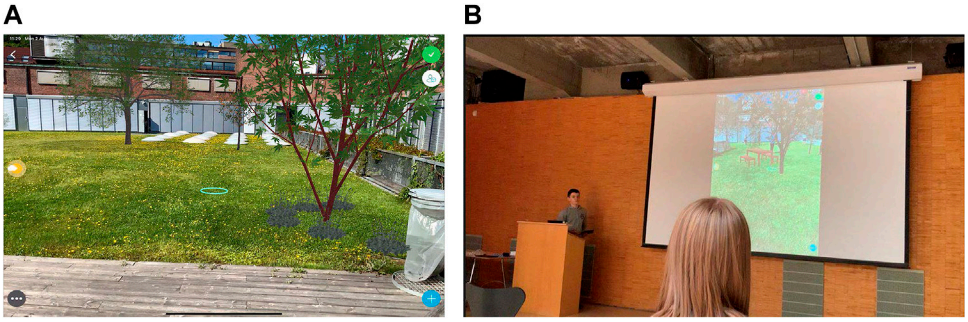

FIGURE 11
Panels **(A, B)**. Introduction to Case study. Panel **(A)** (Left): Participants training in a controlled setting for the first task of the workshop. Panel **(B)** (Right): Participant presenting this first work.

FIGURE 12
Panels **(A–D)**. Users placing trees in situ through AR.

of Architecture and Design (AHO), and research assistants were allocated time to help the youth participants learn the AR application, how to screen record from the iPad, and how to take a screenshot of their proposed designs. A time of 1 h was allocated to this task. Participants were then asked to present their first test case to the rest of the workshop participants through their screen recording and screenshots directly from the iPad. This gave us feedback to ensure that each participant could perform the tasks and present their work to an audience (Figure 11).

Following the introductory training exercise, participants were asked to study possible sites for tree planting within their local neighborhood. This was performed by giving them maps of their local areas and using Google Maps and Google Street View to "pin" areas. Some sites had already been suggested by the municipality. Assistants helped the participants if they had questions. The latter often knew about areas in their local community that they thought would benefit from having more trees. We spent approximately an hour on this task. Following this, all of the sites were collected into a common map within the iPads, and participants were asked to show their maps. We then used the common maps to plan the following days of the workshop. The sites for the workshops were chosen based on these data.

The main part of the workshops consisted of field work with the AR tree planting task. We spent 3–4 days for a duration of approximately 4–5 h each day on this component of the workshop. The sites were those identified by the youth during the introductory session, in addition to those suggested by the municipality. In addition, during the first set of workshops in 2020, we were provided with feedback from the youth on additional sites that had been identified *ad hoc* by them during the day. Therefore, in 2021, we incorporated time slots for *ad hoc* sites that were identified by the youth and used a looser schedule to facilitate this type of site discovery by the youth. At the sites, if specific project information or historical data were available, participants were given that information about each site and were followed to each location to point out such critical details, such as where park or road infrastructure was being planned. Participants then used the AR technology on their iPads to digitally plant trees on sites (Figure 12). During this exercise, participants were offered full freedom to design whatever they wanted within the limitations of the technology and the available sites.

In 2020, each site session was allocated approximately 40 min to 1 h per site; following our experiences from that year, the 2021 time schedule was somewhat loosened in order to incorporate a more *ad hoc* flow for site discovery by the youth. This structure typically allowed four to five sites to be visited within a workshop day. Public transportation was utilized when necessary to move quickly between sites. Other sites were within walking distance, which also facilitated the discovery of *ad hoc* locations during the workshops. The use of walking and public transport was meant to provide participants with an opportunity to consider the context of their sites in the larger context of the city and their normal everyday lives. Our field notes and the screen recordings revealed that, during these walking and transportation periods, participants would often discuss and compare their designs. We also noticed from screen recordings that the youth could perform activities that could be considered "outside of the plan" but that we assumed could also be about building trust, gaining access to information about the technology, or testing the

FIGURE 13
Panels **(A, B)**: At the end of the workshops, Youth presented their designs to politicians and experts.

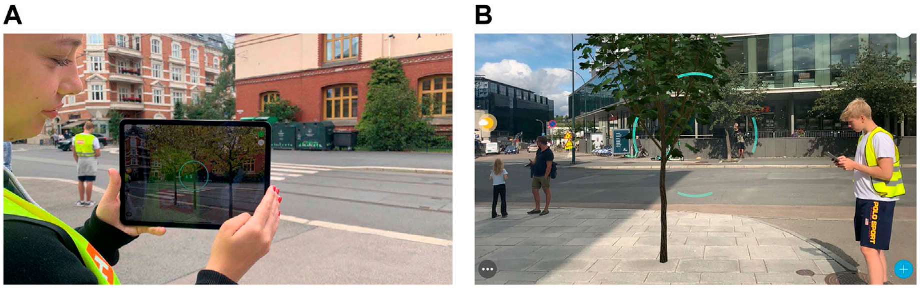

FIGURE 14
Panel **(A, B)**. User shows their design.

social dynamics. Hagen (2021) notes that informal conversations during the breaks are where the most important participation inputs occur, such as deeper insights into the ideas and wishes of the youth. Here, we noticed in our field notes that the youth were curious about a range of issues, including future study choices, employment opportunities, and the general labor market.

At the end of the workshops, participants were asked to review their work on their respective iPads and collate their favorite proposals. Because these collections were ordered chronologically, they provided the research team with a qualitative assessment of the youth's judgement of their own designs and of their learning process during the five-day workshop period. In addition, as these collections reflected the youth's personal selection of preferred designs, we could see the extent to which the municipality chose the youth's preferred designs over the entire collection, thus allowing the research time to better understand what stage of the Ladder the workshops could be placed within. All this work was simultaneously uploaded to the cloud for safe storage and was later sorted based on geographic location. This resulted in two sets of data: those selected made by the participants themselves and the entire data collection from all sites, which again permitted both a quantitative and qualitative assessment of the data—both the entirety of the proposals across the entirety of the city as well as the youth's specifically chosen proposals in specific locations.

The resulting data from the case study consisted of thousands of images and approximately 30 h of film screen recording, which proved to be overwhelming for the research team. Based on an assessment of the cloud data and a placement of several sample sets of trees at selected sites, we estimate that 8,000 trees were placed by AR during the workshops. However, we noticed through the sample sets of selected sites that many of these trees were in similar positions and would overlap with each other if all were to be planted. Therefore, based on the sample sets, we roughly estimated approximately 5,000 original tree placements if overlapping design suggestions were consolidated into single suggestions. Furthermore, if we then assumed that such a technique could facilitate for the projected goal of 100,000 new trees by 2030, based on the participant group sizes, it seems that such a process could be feasible if groups were scaled from 9–18 participants per week to something like double or triple the number of participants, equipment, and facilitators.

Alongside the process of data collection, selection, and archiving it into a secure location in the cloud, the last day of workshops consisted of presentations of participants' chosen work. The research team scheduled 'review' sessions with involved members of the project from the municipality, the research team, district officials, and other interested parties. The participants were then asked to present their own designs to politicians, local officials, and their peers (Figure 13). In some cases, media were present to document the event. Some of the workshops were also documented in local newspapers. These presentations helped further determine the degree to which AR allowed for specific degrees of control on the Ladder because the same material that the youth created in AR was also replicated through the observation material of films, images, and screen recordings. These presentations also allowed for policymakers to make judgements on whether to continue the project into the coming budget year and the need for any changes. Therefore, it is likely that the presentations from the 2020 group played a role in securing the second round in 2021.

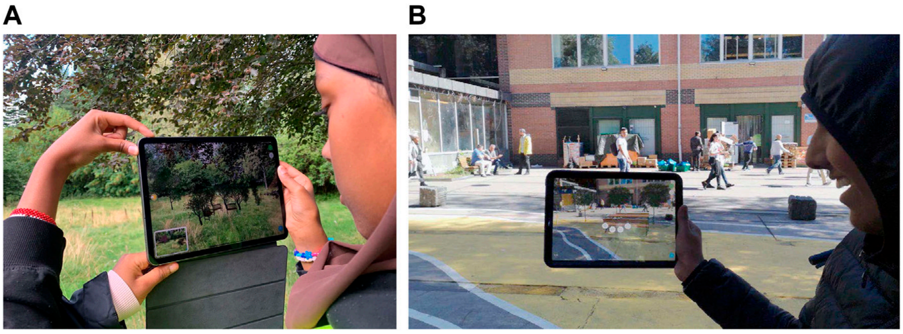

FIGURE 15
Panel **(A, B)**. Users screenshot a design from a chosen vantage point.

3.2 Findings

As mentioned in the Methods and Results sections, our data collection consisted of images, films, field notes, interviews, and the case study material itself in the form of the AR proposals that the participants created, assembled, and self-selected into preferred collections. Some of the most useful data were created by the participants themselves through screen recording not only their process of using AR for urban planning on their iPads but also the manner in which they chose to screenshot specific vantage points of their designs (Figure 14). This helped us understand how the application was being used by the youth, how interactions within AR in urban planning may function, and the design proposals that the participants had made (Figure 15). From this process, we recorded over 10 h of film files and hundreds of images which were sorted by user and site in a folder structure, thus allowing the material to be analyzed.

Participatory planning in not normally conducted with AR tools. Boullier (2016) noted that many innovations are first used as a transposition of previous actions before being translated into something new. We had some initial assumptions that planning trees and objects in AR would vary quite a bit from analog design. As is evident from the images and films documenting the youth interacting with AR and explaining their proposals within the AR application, participants expressed their experience with the AR objects as realistic objects—even when objects are obviously being digitally placed in the world through the iPad screen by the participants themselves. We noticed in our recorded feedback frequent comments from the youth, such as that it was "…cool to see what it will be like with trees," that "This road could be lined with trees," or that "This place could be a garden with trees" (Supplementary Table S5). This seems to demonstrate that the youth participants experienced the AR objects in quite a realistic vision of their own thoughts and ideas for a site.

We saw in the film material from our observations, in our field notes, and in the youth presentations that the AR trees and objects which participants created were also discussed and presented by the youth in a way that reinforced the notion that the AR objects could be experienced in a similar way as trees and objects in the real world. For example, the films we studied from the youth presentations discussed their experience of the AR objects in a present, active tone, such as "These trees allow school children to eat fruit in the break" or "These trees have a nice pink color in the spring." In the recorded feedback (Supplementary Table S5), we also saw that participants expressed, through their proposals, that "This is a place that would be nice to sit/read/play", or "This is family friendly." While there are some studies of VR and fMRI that can help investigate the phenomenological effects of AR objects in the brain (see for example, Sutton et al., 2010), it seems worthwhile to consider how AR objects may be perceived in a similar manner to physical objects, which is certainly a topic for further study.

We wanted to study AR as a participatory tool for youth in a real-life urban planning scheme and understand how it influenced the learning outcomes and decision-making process of the youth. The group interviews demonstrate that nearly all participants learned more about the disciplines involved in the workshop (Supplementary Tables S1–S4). Participants expressed a few times that "It's way better to do it yourself than to just watch the world change randomly" and, frequently, that "I thought it was fun to make my own decision." We also documented the youth stating that "It was boring in the beginning but more fun in end [*sic*] when we could make our own decisions" and that "We made several versions to test out different alternatives" (Supplementary Table S5). The expert interviews documented that "The young people were proud of their work and thought it was exciting," that "The young people seem to have gained an understanding of adult life," and that they "See a development/maturation in the young people" (Supplementary Table S6). This documents some important aspects of the youth learning experience during the workshops and how the youth appropriated the decision-making process.

A recurrent criticism about digital tools is the risk of a digital divide among users (Hasler et al., 2017). An assumption concerning AR research could be that the participants would have difficulty using the application and AR since the technology is in such an early stage of development. This was something we had experienced with user groups in architectural competitions and with architecture and urban planning students, as documented in (Reaver, 2020, 2022). Therefore, we planned to initially incorporate a substantial period of training on the use of AR at the beginning of the workshops. However, after our initial test of this type of training in 2020, we found that such extensive training was not necessary, and even superfluous, with this user group; therefore, this type of instruction was reduced. Our field notes, observations, and screen recordings note how well the participants were able to use the technology and how intuitively they could understand the interfacing, the selection of trees, and orientation in space within the first few minutes of encountering AR. The expert interviews also showed that "The young people thought the technology was easy to use and enjoyed using it" and that "They thought the technology was cool" (Supplementary Table S6). This type of comment was frequently reiterated in the film and image material.

We further studied the case data to try to determine whether the design proposals created in AR by the youth participants were useful suggestions that could be implemented in real life. Here, one could assume that it would be difficult to judge the design proposals of non-expert youth in AR. However, we see from our findings that many of the designs seemed perfectly feasible in a real-world setting (Supplementary Figures S16A, B). Furthermore, we learned after the case study that several of the proposals were, in fact, implemented, with more implementation planned in future.[1] It has been interesting to note that most of the youth proposals are quite similar to a professional design, although without the detail. However, we saw from the data there are many other aspects to consider that were not visible in AR, such as land use rights—since many trees were placed in areas that would be legally difficult (Supplementary Figures S18A, B)—or the size of tree roots, as some trees were placed in a manner that would not be feasible underground. Such aspects could be interesting in considering a future iteration of AR as a participatory tool in urban planning. We discussed in the introduction that some of the limitations to participation in urban planning could be related to how the discipline uses specialized language, tools, legal requirements, and technical specializations. Understanding this complexity of real-world planning in relation to which elements to include in an AR scenario gave us other valuable feedback to consider, such as a future iteration of the tool that perhaps contains zoning data (areas where trees can and cannot be planted) and visualization of a typical tree root system (to show that the size of the roots can be as big as the tree crown). With these aspects considered, it is interesting to consider how AR could be used utilized by non-experts when viewing the high level of design quality achieved by participants who had no previous experience with an early prototype of AR for such a use case. This leads to a further reflection that AR in urban planning could perhaps break down barriers between experts and the general citizenry by providing the latter with some of the specialized knowledge about the AR interface, such as where current plans are located, what types of plans may be considered, and what types of pre-approved trees or benches can be placed within the current planning scheme. We also believe that this could indicate a level of intuitive knowledge that local citizens may have about their environment and its planning.

Through the film observations, the screen recordings, and the participants' own screenshot material, we studied further how AR can interact in a planning scheme. Participants were able, within a short time (a matter of seconds), to place objects on a desired location at the correct scale. They sometimes faced difficulties due to tracking issues in the AR software and hardware, but these errors were often corrected with a second try. Participants were also able to make large proposals by using the "copy" function and could also make collages of many different trees and objects. They often stated their design goal either before or while performing the task and soon displayed the finished design. This shows that AR can be used to quickly generate a proposal at scale corresponding to a desired goal.

We also noticed from the data that there are technical limitations to AR that may limit its usefulness for urban planning purposes. For such use, AR technology needs to have a high enough accuracy for planning proposals to be correctly correlated with physical space. The fact that the material was performed with iPads meant that the metadata in the images and films show the location of the positioning; however, this is not accurate enough for a direct translation from AR data to the planning system used by the municipality. In addition, some AR data indicate the position of objects through their internal coordinates, which is also not precise enough and required manual positioning by the research team after the workshops. For this reason, the actual positioning of trees during the workshop had to be manually configured as a CAD drawing or in GIS. However, we have seen the possibility of including very accurate positioning data in a more accurate geolocation ecosystem. Therefore, in a future iteration (such as with 5G), it would be valuable to find a system that would allow object positioning to be registered automatically in a digital coordinate system, very accurately linked with a planning map or system.

1 From meeting with Oslo municipality and ByKuben 11 November 2022.

4 Discussion

As mentioned in the introduction, the main goal of this case study has been to determine how AR may work for urban planning purposes in a real-life scenario, specifically to study how AR is experienced and used by youth, and how it influences learning outcomes and decision-making. It has been claimed that participatory processes are a way to bridge the gap between designers and users in much of urban design (UN-Habitat and Ericsson et al., 2019), and we wanted to know more about this process that would help us move past theory into practice. Such a goal poses several difficulties due to having to conduct research within a real-life planning scenario. In this case, it meant leaving the controllability of laboratory work and the office to study users and processes within an ongoing planning project. This project has its own goals a direct consequence of current planning initiatives in Oslo—the Oslo Trees plan—with the secondary goal of Oslo's city government effort to integrate local communities in this work, following the *Planning and Building Law*. This project is thus guided by goals arising from recent political shifts in the government of Oslo, the legal framework of participation within the *Planning and Building Act*, and the policy of the Norwegian government, often following the UN. It is important to note the specificity of this case study when considering the research data it produced.

We wanted to know more about the experience of AR to understand the feasibility of AR for greater participation in urban planning. Ertiö (2015) argued that digital tools have the potential to motivate and expand participation, and here, we see results that in many ways confirm this argument. We found that AR can be an appropriate tool for participatory planning, perhaps even especially for the youth. Findings related to the use of AR in a real-world scenario show that our initial expectation that the technology would be difficult to use was highly overestimated. On the contrary, we saw that the technology was easy to use for this user group, and even "cool" (Supplementary Tables S5, S7). We also expected a significant difference between the experience of the digital objects in space and physical objects in reality, but there seems to have been little difference for the participants in their experience of AR in relation to their experience of the real world; rather, participants presented the AR trees as if they were indeed "real." This will have to be considered further when designing future uses of AR.

Arnstein's (1969) ladder of participation as adapted by Hart (2012) and developed by Norwegian Department of Child, Youth, and Family Affairs stated an explicit goal of reaching the top step of the ladder: citizen control or, in the adapted ladder, youth control. We believe from the study's findings that certain aspects of the study could be argued to have achieved this step, especially when youth presented their own designs which were conducted according to their own preferences, and that were even implemented by the municipality. One can certainly argue that AR allows for higher degrees of citizen control due to the nature of the technology as direct, on-site, at scale, and with decisions and interactions in the sole hands of participants.

However, one could also debate whether this top step of the ladder—citizen or youth control—is indeed what was achieved, even in this case. It could be argued that, without any expert guidance (from the municipality, us as researchers, technology developers, etc.), the workshops in this case study would not have been possible to facilitate. While AR is certainly available to citizens, especially to youth on their smartphones, one could also argue that some sort of structure for participation is required. We wonder whether a case without any structure, development, or training would have spontaneously initiated the desired participation from the youth, and what such a scenario may look like. We note here that Hasler, Chenal, and Soutter (2017) suggested a revised ladder for digital tools which they called "empowerment." We recommend further studies on participation and specifically recommend considering specific revisions to Step 8 of the ladder in participation planning to be feasible with digital tools which allow for full citizen control or empowerment.

Cardon (2015) noted how new issues are emerging with digital participation in which data act as an exchange interface between administration and citizens. The interviews, both group and expert, show that the youth appreciated being listened to, and that the municipality can use the data produced during the workshops. However, we must be careful in how we study youth and conduct research. This applies to urban planning, technology design more generally, and especially to new technologies such as AR. Our research showed us that youth learned about the respective disciplines of the study through the workshop format (Supplementary Tables S1–S4), which we hope will be seen as a positive aspect of involving youth in research. We find that this may be especially relevant when considering the findings from expert interviews that show that it is important for municipalities to have relevant activities and opportunities for youth, especially while noting comments such as "It is important to engage the young people in specific tasks and get them out of their homes and around the city" (Supplementary Table S7). However, as noted in Cortesi et al. (2021) report notes, there are many unknown potential dangers at the interaction of youth and AR.

Within interaction design, participation is seen as a method for evaluating user experience during preliminary design or planning. This case study presents some methods for evaluation of an already completed project which could be useful for other studies. For example, a post occupancy evaluation (POE) in architecture is a method for analyzing the user experience of a building or of an urban plan user who has occupying it after completion. POEs are usually conducted at least six months after finalization. Whilst POE has received comparatively less academic attention than other fields of study, interest in the area is growing (Roberts et al., 2019). In some countries, POEs are becoming mandatory in public projects (Hay et al., 2017). Methods for POEs include observational walk-arounds to gather initial information on the performance of the new buildings and consultations with all building users *via* questionnaires and focus groups (ibid).

If we consider tools such as AR in participatory planning, we may speculate on methods that include the methodological aspects of POE such as user observations and questionnaires being included in the initial design phase, and perhaps, even further, how AR could be integrated into initial design and planning such as in this case study. Such a method would entail something like a "preoccupancy evaluation" or PrOE, which would perhaps inform designers of important user experience information during the preliminary concept period. In fact, Shin et al. (2017) have proposed a method of PrOE which can evaluate and improve a design prior to construction by simulating user behavior in the design's virtual space. Shin et al. proposed that PrOE "…can overcome the limitation of the conventional approach of design evaluation in that it evaluates designs in advance by reflecting on user requirements, thus making efficient design improvements possible" (ibid). Notably, thee authors utilized 3D models in a laboratory setting rather than field work in AR, but we could, of course, speculate on the use of AR in such a manner; this case study shows an initial inquiry into how such a process could be conducted. We may thus suggest that the case study may have in fact explored some notion of PrOE as a design method in early-stage urban planning, and we recommend that further case studies take the possibilities of AR as a method of PrOE into account.

There are several benefits in considering the expansion of youth participation and using technologies such as AR. Hagen and Andersen (2021) find opportunities for creative and new thinking are great when young people are invited to participate in the planning of a neighborhood. One potential benefit here is that youth participation, in addition to fulfilling important municipal planning goals, can also foster a sense of engagement and empowerment among youth. Digital tools may be more natural for youth to use, while experimenting with new technologies for participation alongside youth can additionally motivate youth to feel competence and empowerment while also providing researchers important insights into the potential use of new technologies. For example, Hagen (2021) found that trial and error in the digital world opened the eyes of youth to concepts that merit further consideration, including hybrid participation workshops.

An important argument regarding the role of youth participation in planning is the need to foster stewardship for the environment among the coming generation (UN Habitat and Ericsson et al., 2019). By allowing youth to have a say in where important planning decisions are made, such as where new trees are planted, they may feel that they have a stake in their community and are contributing to the overall health and wellbeing of the environment. This can lead to a sense of ownership and pride, which may encourage youth to continue involvement in environmental efforts. Involving youth in the tree planting process can also provide an opportunity for experiential learning about a variety of environmental topics, such as ecology, biology, and sustainability. Hands-on activities and participation can be an effective way of engaging youth in learning and help them develop a deeper appreciation for the built environment and the natural world. Allowing youth to choose where to plant trees may enhance the meaningfulness and relevance of this learning experience. Overall, involving youth in the decision-making process regarding tree-planting may have multiple educational and empowerment benefits.

It is important to note that are also several reasons why youth may not have the necessary expertise in an urban planning scenario—such as, in this case, how they make informed decisions about where to plant trees. One such reason could be a lack of specialized knowledge, such as particular tree species, soil types, and local climate conditions. This information is essential in determining which trees will thrive in a particular location and how they may impact the surrounding ecosystem. Therefore, without this knowledge, youth may make decisions that are not well-suited to the specific conditions of a given location, leading to the potential failure of the trees or negative impacts on the environment. In addition, young people are not likely to have experience in planning and implementing large-scale tree planting projects, which can be a complex process requiring careful consideration of factors such as logistics, funding, and permission.

Therefore, without the necessary experience or resources, the youth may be unable to effectively navigate these challenges. Furthermore, they may not have the expertise to assess the long-term impacts of tree-planting decisions. While the immediate benefits of trees, such as aesthetic value and carbon sequestration, are important, it is also crucial to consider how the trees will grow and change over time and how they may impact the surrounding environment and community. Without the necessary knowledge or experience, youth may not be able to make informed decisions about these long-term impacts. This seems to highlight the importance of finding the correct input of expertise and guidance within participation scenarios. Furthermore, from a technology development perspective considering the future of AR, consideration is needed of how various levels of expertise in participation could be integrated into the interactive features of an AR app, such as zoning data, size of tree roots, and applicable planning areas. This case and others like it can hopefully open opportunities for creative ideas for both AR development and participative processes in urban planning.

Finally, we believe that there are several potential factors evident in the study that highlight the benefits of AR in motivating youth to engage in the design of their own environments. One such factor may be a desire for independence and self-expression. The creation of spaces that reflect personal interests and personalities can provide a sense of agency and control over one's surroundings, which may be particularly empowering for youth. In addition to personal motivations, youth may also be driven to design their own environments to address issues or problems in the world around them. This may include a desire to create spaces that are more sustainable or inclusive. Engaging in the design process can provide an opportunity for them to utilize their creativity and problem-solving skills, potentially leading to a sense of personal fulfillment and accomplishment. It may also serve as a means of making a positive impact and contributing to the greater good. New technological domains such as AR development in collaboration with youth participation could be an important step in developing a more democratic and sustainable approach to the challenges of both urbanization and digitization.

4.1 Further work

Following the case study in the article, we have had multiple meetings within the research team and with the municipality of Oslo to plan any steps forward. A new set of case studies were conducted in 2022, which will be discussed in coming articles. An important development here was the expansion from focusing not only on youth and the Oslo Trees project, which has continued, but also prototyping the use of AR as a participatory planning tool on another project in Oslo that focuses on car-free streets and including local neighborhood participants of all ages.

One of the main discussions about further work concerns the issue of implementation beyond cases to a more general participatory structure in Oslo. It is important to figure out how to coordinate participatory planning with AR tools into a GIS mapping system. As discussed previously, due to the current precision of AR technology, most of the translation from AR proposals to planning submissions has had to be manual (Supplementary Figure S20). However, at least in theory, this manual work could be automated by directly mapping GIS data onto AR proposals. Through wireframing, we have started to prototype such a solution (Supplementary Figure S21). We hope to develop this research in a future iteration of such case work and in more general AR research that focuses on applications in the built environment.

Through multiple national and international conferences, lectures, and other events, we have had the opportunity to share some initial components of this research with a broader scientific and policy community. The support for our research has been very positive, suggesting that the topics we address are relevant to a variety of contexts and research considerations outside of the immediate case and within broader contexts of AR development, participatory planning, youth participation, and design methods that focus on user experience and participatory design. Within the so-called 'smart city' discourse, we have also been given technical guidance on how to coordinate various GIS positioning and coordinate systems.

We have also seen a particular emphasis in the discourse on the idea of local community engagement and, in particular, the empowerment of youth through participation and an emphasis on education and research into new technologies. Inclusion of the cases within the Cortesi et. al. (2021) report on Youth and Extended Reality has been particularly interesting to note, as the report states that while immersive technologies hold great promise for learning, creativity, and self-expression, they also come with risks connected to accessibility, privacy, and safety. The concern regarding how AR and similar technologies influence younger generations both positively and negatively will certainly be of interest while moving forward either in Oslo with this case work, or in other contexts around the world.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the AHO, Municipality of Oslo. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s) and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2023.1055930/full#supplementary-material

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