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Augmenting Community Engagement in City 4.0: Considerations for Digital Agency in Urban Public Space

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Abstract: An engaged community that reflects a diverse set of experiences is key to an equitable and livable city. However, maximizing engagement activities is often difficult when competing with residents' busy schedules and hectic daily lives. To explore new opportunities in this space, we developed four augmented reality experiences to learn more about the potential for this technology to transform community engagement practices in the context of City 4.0. City 4.0 utilizes digital technologies to transform public services and the local economy. Its goal is to produce more sustainable urban and societal outcomes. Our findings suggest that augmented reality is least successful when used to recreate existing engagement practices, such as surveys or questionnaires, and more successful when it empowers a sense of agency and ownership over the process in its users. The way augmented reality situates information can aid in making public space feel personal to the individual. In this way, augmented reality's affordances are less about overlaying digital information in physical space and more about how this can enable individuals to reclaim a sense of control and relevance in the relationship between citizens and councils. We aim to contribute: (a) novel interaction paradigms and an evaluation of their effectiveness and limitation, and (b) new insights into how to support citizens' sense of agency in public discourse with augmented reality. This paper highlights the value of augmented reality's affordances to bring to light new interactions between community engagement stakeholders.

Keywords: augmented reality; digital agency; urban public space; community engagement; placemaking; human-computer interaction; smart city; city 4.0; urban planning and design; Brisbane

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1. Introduction

The last decade has presented many challenges for cities around the world. First and foremost, urban migration continued to rise as projections estimated the world's urban population to be as high as 68%. As of 2020, North America's urban population is estimated at 83%, Australia at 80%, and Europe at 75% [1]. The past two years have also seen the COVID-19 pandemic challenge city resilience and slow forward-looking policy in response to handling the immediate emergency and uncertainty about a future 'post-COVID-19' recovery [2]. Rapid population growth in cities often requires changes in the urban landscape to accommodate for new housing, mobility, and other shared services. These changes can often affect large amounts of the pre-existing population. For these changes to be well-suited to both new and existing populations, city administrations will often look to community engagement strategies that hope to inform and consult with those most affected. In doing so, city administrations can attempt to ensure their decision is more defensible against critiques and the project is less likely to encounter roadblocks or pushback. The concept of City 4.0 introduces a new paradigm in which city administrations utilize digital technologies to connect all city stakeholders in a way that produces more

sustainable urban outcomes. Furthermore, community engagement is a broad term used in an urban context to describe the different types of engagement from citizens in urban issues [3]. While research can often discuss this in terms of participatory planning [4–6], we utilize the term community engagement because it is a term shared by both researchers and city administrations alike.

Research on community engagement puts a strong focus on the politics of participation and how different approaches to community engagement can have vastly different results [7,8]. Participatory and collaborative approaches particularly look at broadening the base of stakeholders involved, and especially at 'giving a voice' to traditionally marginalized groups [9,10]. The community engagement literature has seen a few interesting new developments in participatory design methodologies [11], interventions within public space [9,12], or applications of novel technologies [4] that address the challenge of inclusion. Furthermore, the COVID-19 pandemic has accelerated the adoption of QR codes and remote communication, whilst Facebook's announcement of their 'metaverse' plan brings concepts of mixed reality and blockchain to the mainstream, offering new opportunities for technologically mediated interactions in community engagement processes. Likewise, the new and popular city blueprints, such as smart cities or City 4.0, also underline the crucial importance of community engagement [13–16]. City 4.0 utilizes technological developments and digitalization to transform local public services and the local economy. It leverages these digital technologies and data to connect citizens, producing sustainable and desired urban, environmental, and societal outcomes for all.

In the context above, augmented reality (AR) is gaining attention as an enabler of situated engagement [17], improved urban conversation [18], and participation in cities [4]. AR allows digital information to be situated in physical space, so in an urban context, development details can be shared between stakeholders at the physical location or displayed and embodied at scale. The main affordance of AR—to overlay digital information over the physical world—is touted as a key driver in encouraging engagement with planning proposals, or in consulting with citizens about future developments [5,18,19]. Whilst there has been research into what this can mean for co-design in participatory planning, it is noted that the greater political systems in place still ultimately decide the face of participation in any given engagement process [4]. As such, a critique of AR or the implementation of any novel technology in cities is that, while the technology may offer new interactions, without a fundamental shift in the political relationship between councils and citizens, the technology will simply offer new opportunities for top down 'engagement theatre' and consensus building activities.

Our research studied four different AR experiences intended to explore bottom-up and middle-out forms of engagement. The experiences ranged from the recreation of existing community engagement methods in AR to entirely new interaction paradigms used to blend physical and digital.

- The city builder: This experience presents a list of options that allow the user to build their own city in augmented reality. Each option queues a separate musical loop, so that they end with a unique city and song. This experience was intended to test how AR could offer new interactions for gathering feedback from the community and visualize the results of citizen choices back to the participant in real time.
- The city spaces quiz: This experience acted like an augmented reality photo gallery, showing photos of space designed for cars or for people. It was designed to highlight the large amount of space required by cars, compared to people. Users would be quizzed on what level of scale they thought the photo represented. We intended this to be a form of interactive and educational tool that would help us gauge how receptive individuals are to education delivered through this medium.
- Bridges for Experience: This experience displayed 3D models of different bridges overlayed across a map of Brisbane River. Showcasing the potential to demonstrate future development plans to citizens in AR. Like the above experience, we wanted to

understand how users would react to an AR experience that mimicked more traditional community consultation strategies.

- The portals: This final experience displayed a portal in physical space that users could walk through to enter a virtual city. They could walk around this virtual city and experience a virtual world situated in the same space as the physical world.

These experiences were offered as 'probes' to demonstrate different interaction paradigms in context and understand the opportunities and challenges of adopting AR technology in community engagement practices. We offered these experiences firstly to participants as part of a city-wide STEAM festival that lasted three weeks and secondly in a half-day workshop with four participants.

What emerged from our findings is that a key value of augmented reality for improving community engagement practices is not just about the unique interaction paradigms it affords, but more so about what opportunities it represents for the individual citizen within the community engagement political dynamic. Participants often discussed the feelings of agency that our city builder and portal experiences offered, and that while the interaction itself was novel, it was more that the participant felt that their voice was heard and that they were contributing. Participants were much less interested in our one-way informative experiences like the gallery, and much more interested in the experiences that allowed them to create for themselves.

Therefore, we contribute that, while AR affords us interesting opportunities to overlay digital information in physical locations, this is perhaps only relevant in community engagement when it empowers a sense of agency in the individual engaging with it. Simply put, a recreation of existing engagement processes in AR are unlikely to be successful purely because of AR's affordances, however, AR's unique affordances do allow for an improved sense of agency for individuals in public space and a rethinking of the greater engagement experience. This was evident in the responses of our participants between the city builder and the Bridges for Experience. While the Bridges for Experience and city builder both use AR to overlay digital information on the physical world, the city builder was much more positively received due to the information being created and customized to hold significance to the end user.

Below, we explore the literature surrounding community engagement, participatory planning, and urban human–computer interaction (HCI). We do this to explain our use of the term community engagement and situate this focus within the participatory planning literature. Furthermore, it is important for us to draw on the urban HCI literature to contextualize our findings and show how urban HCI research has previously conceptualized the use of AR. Following this, we discuss our early conversations with stakeholders, our reasoning for and design of each study and the results that we found. We then highlight the areas of interest that emerged from these studies before finally discussing some interesting directions for future urban AR research.

2. Literature Background

2.1. Community Engagement and Participatory Planning

We start this related works section by highlighting the literature surrounding community engagement and participatory planning. In most urban research, participatory planning is the term used to highlight the relationship between councils and citizens in relation to the development of urban areas [6]. However, the term participatory can carry slightly different meanings that shift the focus of research in the area. In the context of participatory design, participatory planning will often focus on the individual and design interventions, such as media façades, urban screens, and mixed reality, that encourage participation in design with individuals from the bottom up [9,20]. In other cases, the focus of participatory planning research is more political, analyzing varying levels of civic participation in relation to greater democracy. In particular, Legacy's [8] paper highlights the way a large majority of the participatory planning literature tends to analyze top-down and bottom-up perspectives and how they can affect participation. While these topics certainly

are not mutually exclusive, it is worth noting how the focus can shift from participation as an individual design activity to participation as a civic duty or participation within political process.

Smith [6] presents an interesting summary of this, defining the rational and consensual aspects of participatory planning. The rational aspect considers that "individuals are more intimately involved with environmental changes; they can provide a planning process with information and judgements regarding local systems". The consensual aspects consider "societal units, being involved in the determination of planning processes related to the domain of that societal unit, which may lead to a further integration of power with authority, a move toward a democratic society". This theoretical basis for participatory planning [6] posits these two aspects in a way that has been accurately reflected in the analysis of research for years to come. We relate the rational aspects more closely to participatory design research, and the consensual aspect as the political focus of participation.

One constant in participatory planning research, however, is its focus on planning processes. That is, most of the participatory planning research understandably conceptualizes participatory planning as something related to a specific project that will invite change in the urban area. A gap that arises in this literature is that its strong focus on planning processes and the politics of participation narrow its focus in such a way that it can miss the other motivations for engagement exhibited by citizens. To further this, community engagement literature has covered engagements between different stakeholders in medical research, such as the cultural barriers regarding the uptake of a vaccine [21], or in education research, to help embed cultural knowledge in an educational curriculum [22]. Aligning with the community engagement terminology, we are able to draw insights from city administration practice and the broader engagement literature perspectives, inclusive of participation, planning, and politics, but not restricted to these lenses. With this in mind, we utilize the term community engagement for two reasons: (a) community engagement is not specifically tied to the planning and development of an urban area, but more so to citizens' engagement with councils, and (b) community engagement is often utilized as a tool by city administrations within participatory planning processes. In the first instance, community engagement allows us to investigate the relationship between councils and citizens from a broader perspective, rather than in relation specifically to urban planning. Secondly, often in practice, community engagement is the terminology used for strategies that encourage broader participation. In this paper, we often refer to traditional community engagement strategies and therefore feel it relevant to use this terminology as our basis for comparison.

2.2. Top Down, Bottom Up, and Middle Out

When analyzing community engagement strategies and the relationship between city administrations and citizens, there are often three different relationships that are discussed: top down, bottom up, and more recently, middle out.

Top-down relationships position engagement as led by city administrations or governments, and often focuses on the way that city administrations consult with communities or deliver information to communities [8,23]. This form of engagement, when critiqued, is said to be more performative or see the role of the citizen as tokenistic [24,25]. This is often because the decisions regarding the planning have been made, and community engagement is used as a strategy to inform citizens of the decisions. In other cases, it is found that the policy environments and power dynamics between varying levels of government can often sideline community objectives [26].

Bottom-up relationships position engagement as something that empowers individuals to create, design, and actively participate in interventions at a grassroots level [23,27]. While it could be said that some bottom-up interventions could still be empowered by city administrations, they are typically led by a community group, social movement, or individuals and look to collaborate on decision making according to the chosen intervention. In this way, community engagement is a more collaborative process than the post-decision-making

process of the top-down perspective. However, sometimes overlooked in these positions is the challenge of scale and the individual's perceived relevance of the project [26].

Bottom-up projects tend to be driven by individuals or community groups, and the shared purpose of that group adds perceived relevance of the intervention to all members of that group [3]. The projects of city administrations, however, can sometimes be so large that they affect a much wider group of the population and, as a result, it is increasingly difficult to ensure the engagement feels personal and relevant to everyone affected [3]. The final body of literature follows middle-out engagement.

Middle-out engagement looks to draw on the collective knowledge of all actors to provide opportunities for collaborative community engagement processes. The pop-up interventions of Fredericks and Caldwell [9] enlisted the help of both councils and local community stakeholders in their design, implementation, and deployment. These interventions utilized the strengths of both groups of stakeholders to ensure the interventions could be deployed at scale and for the benefit of broader councils, whilst still drawing on the knowledge and design of individuals at a local level to ensure their relevance and value to that local community. More local, state, and national urban policy is moving in a similar direction with a recent white paper from England's Ministry of Housing, Communities and Local Government proposing that better information be delivered to local communities, and technologically mediated solutions be developed that allow for a more democratic system between residents, communities, entrepreneurs, businesses, and councils [28]. Furthermore, research by Usavagovitwong et al. [29] highlights the concept of 'community architects' across Asia, specifically demonstrating the value of architects in enabling a link between poor communities, local organizations, planning and development agencies, and broader government initiatives. In both of these works, the value that comes from enabling engagement between all city stakeholders and adopting a middle-out engagement approach is made clear.

Our research aimed to explore the value of a middle-out engagement approach, by partnering with local councils to host our digital experiences and offering interactions that specifically elicited feedback and knowledge from individuals and included their participation through creation within the experience. We ultimately wished to explore how this approach can develop into more conversational platforms between citizens and councils, where the middle-out ethos can be coupled with urban HCI interventions that contribute to a broader city platform. We summarize the three approaches in Table 1 below.

Table 1. Engagement approaches.

Approach	Definition	Advantages	Disadvantages
Top-Down	Led by city-administration. Tends to deliver information regarding planning decisions.	Can deliver information at scale, and utilize existing IT infrastructure.	Often feels 'tokenistic' as citizens are not included in decision making. Little engagement from citizens as perceived as irrelevant and impersonal.
Bottom-Up	Led by individuals or community groups, designs grass-roots solutions with citizens.	Relevance to particular group, further engagement due to personal feel. Collaboration before decision making.	Difficult to scale, solutions specific to smaller urban groups. Often niche issues, and under-resourced.
Middle-Out	Aims to utilize knowledge of all actors, enlisting the help of councils to facilitate, and individuals to contribute.	Utilizes the value of all stakeholders, facilitates a relationship between stakeholders that is usually challenged.	Limited previous work to draw on. Broader group of stakeholders makes project planning and execution much more difficult.

2.3. Urban Human–Computer Interaction

Urban HCI is often discussed in research in both the context of community engagement and the context of social movements and digital activism. Like the way in which participation can be viewed through a political lens and a more design lens, the intersection of public space and technology often explores the way technology can shape the political landscape at a grassroots level, and the way individuals can use technology to create and

design their own communities or experiences within that space [30]. Vadiati [31] highlighted the shift technology has on public space into an augmented urban space continuing beyond its physical boundaries. Furthermore, the way this matter affects urban governance was discussed, noting the narrative across research that ICTs are ultimately activating more citizens who would not engage in urban matters through traditional outlets [31].

While the influence of communicative technologies in urban space is increasingly evident, there are still many facets to explore around their implementation, the interactions they offer, and how they may or may not shift the current relationship between citizens and city administrations. Analysis of digital activism and citizen science [18,32–34] has highlighted the power for communicative technologies to empower individuals and social movements, such as the global effects of #MeToo and #BlackLivesMatter; however, the fact that these issues can transcend national boundaries can sometimes be to the detriment of their relevance or impact at the local level [18]. Alternatively, e-participation research will often investigate digitally mediated participation at a more local or state level, although this tends to revert to a focus on participation in planning or governance processes [4,35,36]. Ultimately, while there is a growing amount of research looking into the implementation of novel technologies at a local level, most of the focus lands on how these technologies can augment planning processes.

AR has been utilized many times in recent years as a tool to test new co-design methods for city planning. Its strengths as a visual communicator—allowing users to place objects and visualize proposals—is often touted as a key reason for its value in co-design methods, and its ability to run on modern mobile devices is seen as an incentive for younger audiences. In Bandung, Indonesia, augmented reality was used as a learning tool for future environmental planning. In this way, augmented reality allowed for more interactive storytelling that could combine local folklore with environmental challenges and was found to be adopted by the students in such a way that they could communicate to other community groups through augmented reality to collaborate on solutions to environmental challenges and educate those less aware of environmental issues [37].

Furthermore, in New Zealand, Allen et al. [38], developed an application that allowed members of the public to visualize 3D models of new building designs at their proposed physical location. The participants responded extremely positively to using AR as a visual tool in this way. Since 2011, many similar studies that use AR have taken place to co-design urban spaces, and in particular buildings and future developments [5,39]. Lastly, a paper by Saßmannshausen et al. [4] highlighted the value of these AR tools as extensions of community engagement practices that can entice a younger audience's participation. While this work was still grounded in planning activities, it also explored how AR can be used as an informative tool, a co-determination, and a co-design tool. In this context, it was not just about visualizing existing plans, but about encouraging participation in the design of these tools that would then visualize information.

One aspect that we find particularly interesting is how using AR for participatory planning can open up to new co-design possibilities outside the immediate realm of planning. That is, by enabling users to place and visualize digital objects in physical space, we can also enable new possibilities for collaboration between these individuals in public space. Furthermore, the development of algorithmic techniques allow for a procedural generation of building designs, so that architectural expertise can be generated without the need for expertise from the individual citizen [40]. In particular, Potts [41] analyzed the way PokemonGo and augmented reality games (ARGs) could activate public spaces, increasing community interaction and facilitating the exploration of a city. Furthermore, numerous studies have explored the impact of AR to reappropriating public space [42,43]. These studies highlight the way these tools can be used for empowering individuals in urban space, not just in a planning context, but in the broader relationship between citizens, city administrations, and public space. Our research seems to sit at the intersection of these few topics.

In sum, we use the term community engagement because we understand AR's affordances to extend beyond participation in planning activities and empower more broad community engagement. Having said that, we are not purely focused on the political empowerment of communities in opposition to city administrations in the city–citizen political paradigm. Lastly, while we recognize the value of AR as a visual tool in cities, in this work, we wish to explore what that means for improving the engagement of an individual within their community and public space, especially considering the smart city or City 4.0 context.

3. Methodology and Analysis

The research took place over a period of about 12 months across several meetings with relevant stakeholders and two main studies. Our team consisted of two interaction design researchers and a post-doctoral game developer with expert knowledge of Unity3D and ARCore. This research is part of a broader exploration of augmented sociality [44] that seeks to find new opportunities for a community-oriented, user-generated mixed reality. Augmented reality itself is most easily understood as technology that overlays digital information over the physical world [18].

Preliminary research into smart cities [45] highlighted a shift in focus for city administrations from implementing technologies to address the assumed needs of urban challenges to instead using communicative technologies to talk to citizens and understand what challenges existed [18].

Given that our aim was to explore new opportunities for a socialized AR, we reached out to local stakeholders to understand their perspective on the state of current community engagement practices. For sake of clarity, we will summarize the main insights gained from the stakeholder meetings in this section, because these informed the design of the four AR probes adopted in the subsequent studies. The findings from the two main studies are presented and discussed in the next sections.

The first study was conducted in the wild [46,47] during a public festival. As Rogers noted, research in the wild "is likely to reveal more the kinds of problems and behaviors people will have and adopt if they were to use a novel device at home, at work, or elsewhere" [46]. While studies in naturalistic settings often follow preliminary lab studies, we decided to conduct this preliminary exploration in a relatively uncontrolled setting with the aim to reach a wide public audience and gain an understanding of general expectations, technical challenges, and public interest.

The second study, conducted over six months after the public exhibition, consisted of a half-day workshop with four participants, during which specific thoughts on community engagement and the AR probes were shared and discussed. The workshop adopted an approach inspired by future technology workshops [48,49] and cross-cultural dialogical probes [50].

3.1. Stakeholders Consultations

Initial discussions involved employees of the Brisbane city council in various offices with responsibilities spanning across community engagement and digital services. Since these consultations involved all participants in their professional roles, with a view of discussing possible collaborations and partnerships, these conversations were not conducted under the project's ethical framework and no 'informed consent' declarations were collected at the meetings. We nevertheless omit reporting on their detailed roles or positions to maintain confidentiality. No audio or video recordings were made of these meetings and the summary below is based on the authors' detailed notes taken during the meetings. To ensure the participants' viewpoints are correctly represented, we shared a draft of this paper with them, seeking comments and inviting corrections.

The discussions focused on the technologies that were in use or that the stakeholders were potentially interested in and how these played a role in different community engage-

ment strategies. We also discussed, in their view, how augmented reality may be utilized to address the challenge of community engagement at scale.

3.1.1. Opportunities

It emerged that collaboration and engagement were among the biggest use cases for introducing technological innovation in public projects, with a particular focus on connected community spaces and socialized or virtual platforms. The principle of fostering agency and sense of ownership was an important driver, in line with existing initiatives currently supported through more traditional means.

One important aspect was the drive to support existing community groups in implementing local engagement programs and to remain financially viable, rather than exclusively focus on large scale centralized support. Supporting these localized groups involves a deep understanding of how they operate, both internally and within the complex ecosystem of municipal offices and regulations.

Overall, a specific interest emerged for tools and applications to help deliver infrastructure projects. This involves supporting various goals and phases in a typical infrastructure project, from seeking feedback in the designs, informing the public on intended outcomes and benefits, and engaging with the community to help understand the project and create the best possible experience. This is within the understanding that councils ultimately own the assets and high-level planning decisions have typically already been made at the time consultation begins. It was noted that these processes are currently mostly supported by rather low-tech tools, often paper-based, or at best, online services.

3.1.2. Challenges

It also emerged that the downside of innovation rests in its inherent high level of risk. Decisions on adopting technological innovation are very sensitive to political cycles, and the availability of resources and funds can be ephemeral.

A particular emphasis was placed on the journey to deploy specific technologies within established council procedures. The need for infrastructure, the challenge of data management, and the community expectations and understanding of new technologies all pose problems.

A challenging goal also emerged from drawing in those who are hesitant and support the accessibility on a community scale with the aim of making the city more inclusive to vulnerable and homeless people. Symmetrically, an important but challenging goal was identified to explore new ways to gather, analyze, and use data from community engagement tools and initiatives.

3.2. Augmented Reality Probes

Following our preliminary stakeholder meetings, we distilled several design inspirations that we further developed through discussion in the research team and based on the relevant literature and previous works:

- Engage new audiences and members of the public who are otherwise hesitant to participate in community initiatives;
- Explore synergies with data mining, visualization, and data driven decision making;
- Explore unique affordances of augmented reality, especially the appeal of visual interactive tools, localized contents and interactions, and similarities or resonance with virtual reality;
- Maintain a focus on deployment and accessibility by a broad audience.

While developing the AR probes, an opportunity arose to present them to a very large audience as part of the Curiocity festival. This STEAM festival has a strong focus on using science, technology, engineering, arts, and math to curate interesting public exhibits throughout Brisbane. Its goal is to encourage people to navigate around the city from experience-to-experience learning about both the city and the various applications of

STEAM. The festival ran for three weeks throughout March and hosted over 60 installations, at least two thirds of which were utilizing augmented and virtual reality.

Curiocity aligned extremely well with our initial research agenda as it allowed us to showcase the experiences to the public and to gauge an interest in the public for augmented reality usage under the broader theme of the festival.

However, this opened our research to a whole new spectrum of challenges. Of course, being hosted by the Curiocity festival, the location of our installation was decided for us, which was outdoor. Secondly, being a part of a broader festival meant our participants would not be solely engaging with our exhibition and therefore would have little prior understanding of our installation and its purpose. Challenges like these shaped a few design decisions as it was important that we developed something intuitive, playful and that could work outdoors.

A range of ideas were brainstormed and assessed based on likely environmental challenges, availability of material or software libraries, COVID-19 constraints for sharing devices or manipulating surfaces. We considered offering a city builder experience, a gallery or quiz experience, a table with a Lego-city and sensors that trigger music, and a final AR wall that would overlay digital information on top of a Brisbane city map. These can be seen in Figure 1.

An important factor in refining the design ideas was to offer a selection of different AR interactions and replicate typical engagement methods. The quiz would be an interesting way to explore how councils could inform citizens in AR, whilst the map would show models in AR and highlight the potential for AR as a visualization tool. However, the city builder, which had been chosen as the first experience, was instead intended to transform previous engagement processes and highlight the way interactive games could elicit the same information as a survey in a more playful way.

Printing Markers

For these AR experiences to work on location, we had to decide whether we would use image recognition or GPS. We could either use spatial anchors to place the experiences in a physical space so that they would be triggered when a user pointed their phone at that location, or we could use image recognition and image markers so that the experience would trigger when the user pointed a device at a particular image. We decided on image recognition for the three table experiences, the city builder, gallery, and model bridges, and spatial anchors for the portal. A spatial anchor was more useful for the portal as it required the user to walk through it, so we could not have a physical obstacle in the way of that interaction.

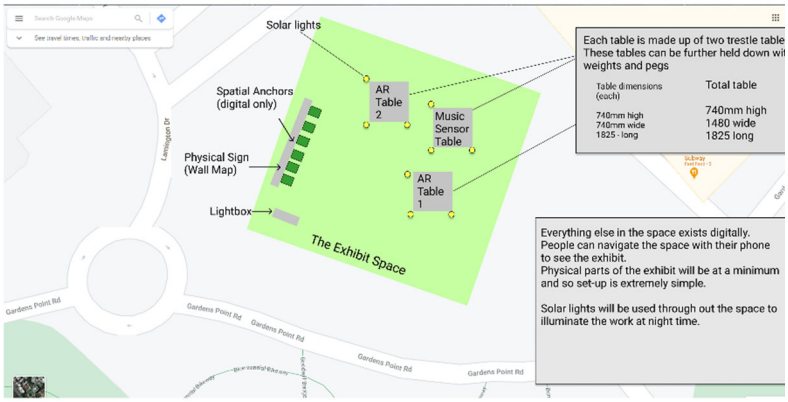

Figure 1. *Cont.*

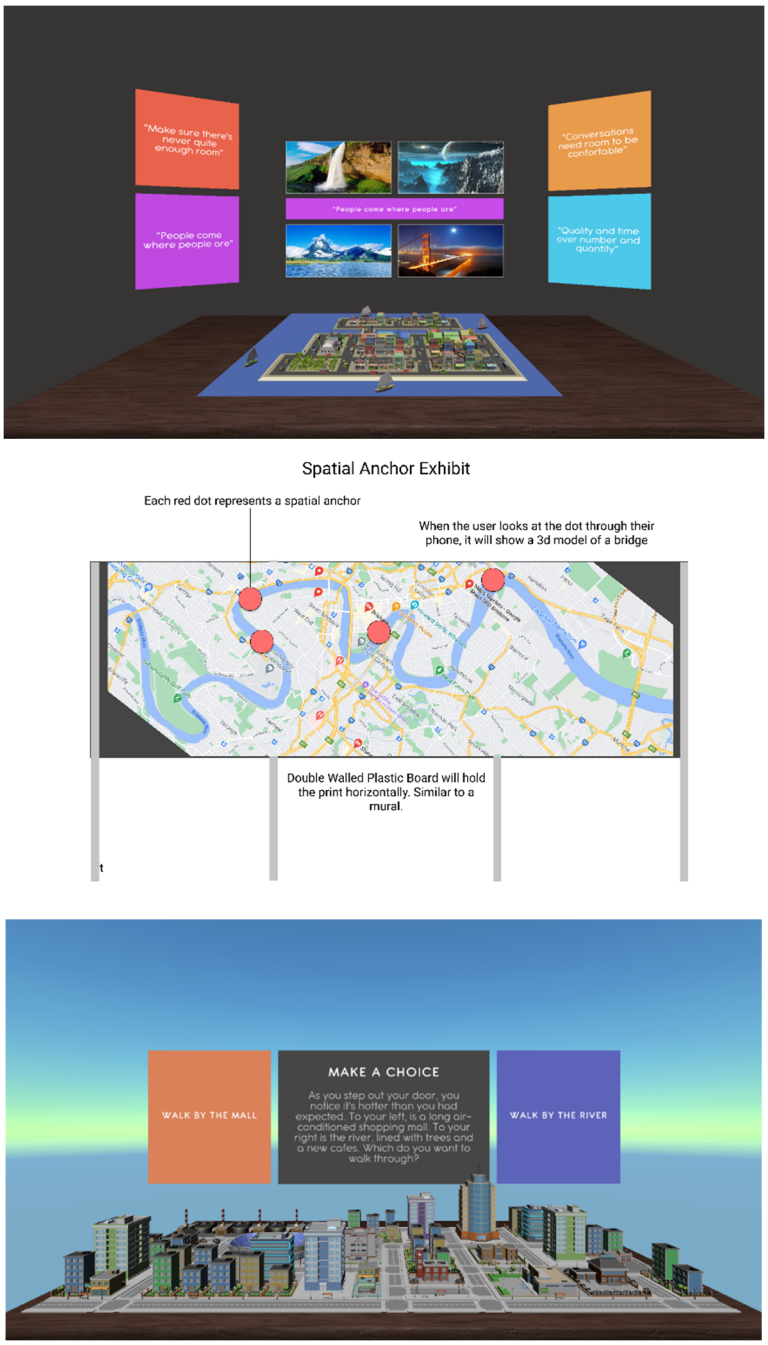

Figure 1. Initial designs brainstormed for the Curiocity Festival.

We wanted to design the markers in such a way that they were recognizable by the image recognition software, whilst still interesting for the participants and indicative of the experience on offer. We decided to double the markers as instructions and measured them out so that they would cover the entire tables we had hired. The markers can be seen in Figure 2.

These markers had to be printed on a specific type of plastic board so that they were water resistant and would not warp in the outdoor area under different weather conditions. The weather resistance of the board was useful, although this added a reflective layer to the marker that caused issues with the image recognition once placed outside. Again, not being able to test these on location, the challenges of image recognition did not become apparent until the markers were in place.

Figure 2. Image recognition designs brainstormed for the Curiocity Festival.

3.3. The Experiences

'Future Cities for Future People' is an Android smart phone application that can be downloaded from the Google Play Store to play. The name is an intended reference to Jan Gehl [51], who largely inspired the ideas presented throughout the AR experiences. The experiences within the application are as follows.

3.3.1. City Builder

The first game is a city builder. We present an empty city grid to the user and ask them to make choices about what should be in the city. Each choice presented is also linked to a musical loop. Once the participant makes all of their choices, they are presented with a unique city and an accompanying song. The choices that we presented to the user are as shown in Table 2.

The choices that we presented to the participant are of course not mutually exclusive in a real-world city planning context and, furthermore, we did not present them with any bias as to what may or may not be the correct answer. In some cases, we could visualize the results of choices, such as parking lots and public transport, wherein the parking lots choice would take up much more city space than if public transport was selected. However, it was not our intention to attempt to simplify what may be extremely complex issues. Instead, it was about presenting a questionnaire in an interesting and playful way to see if there was potential for this kind of conversation between city administrations and citizens moving forward. With the user's consent, their interaction could be recorded so that the choices could be processed and analyzed. Again, this was intended to demonstrate how these interactions could spur real-time conversation between councils and citizens.

Table 2. City builder choices.

Lay Roads	
Standard housing	Highrise buildings
Public services	
Parking lots	Public transport
Supermarket	Market stalls
Stadium	Observation tower
Opera house	Tourist hotel
Stadium	Gardens

Once users had built their city, they could also activate a street view by clicking on a section of road. This would transport the user to that part of the road, and rather than look at the grid, they were free to move their phone around in space and view the city they had built as if they were standing in it. This can be seen below in Figure 3.

Figure 3. The city builder screenshots of third person and first person street view.

3.3.2. Bridges for Experience

The second experience displays a map of Brisbane and its river, pictured in Figure 4. Across the river are interactable buttons that the user can press to see different 3D model bridges. These bridges were designed by students from Bochum's University of Applied Sciences as part of an assessment exploring the education of students within media architecture and their approach to bridge design. The experience allows the bridges to be viewed in 3D space hovering above the map of Brisbane and displays a small description as to why the bridges were designed as they were. This experience is intended to showcase the possibilities for community consultation through AR. Using AR, we could quickly demonstrate future bridge designs to the community, hoping to engage them and demonstrate a way in which councils could engage with communities regarding future urban planning designs. Furthermore, it showcases the possibilities for university, industry, and council

partnerships as 3D models can be exported from architecture programs and displayed within AR applications.

Figure 4. Bridges for Experience.

3.3.3. City Spaces

The city spaces quiz—shown in Figure 5—is intended to be an interactive game that would help citizens think differently about a sense of scale in urban space. Taking much inspiration from Jan Gehl's book Cities for People [51], this game acts like a photo gallery in 3D space, displaying different photos of Brisbane's city environments to the participant. It showcases urban areas that are designed for cars, humans, and both and aims to educate participants on the difference between human needs and needs for cars and the amount of space required for each.

3.3.4. City Portals

The final experience is a GPS located AR portal. This portal exists at the physical location of the installation and can be interacted with by simply walking through it. Users can hold their camera up to the space to see the portal appear, and then walk through to experience an entirely virtual world. The photos in Figure 6 demonstrate how once inside the portal, the users' field of view becomes enveloped in the virtual environment. Here we hoped to demonstrate the affordances of AR as a situated and embodied interaction method.

3.4. The Participants

3.4.1. Study 1: Curiocity

Over the course of the 17-day festival, there were 90 downloads of the application. During the festival there was constant rain for roughly 5 days, and a COVID-19 lockdown for another three. As this installation was outside, this certainly played a part in the number of interactions we received. Of the 90 downloads, we received consent 125 times to receive data about the participants choices. This number is greater because users were prompted

every time they opened the application, so in some cases the participant may have used the application more than once, and therefore consented each time they used it. Of the 125 data logs retrieved, only 43 contained data regarding the users' specific interactions with the application. The remaining 82 display a 'TEST' input, so that we know the application was opened but no further data was recorded. This tells us that no further experiences were triggered, which could be through user choice, or through a break in the applications functionality, such as the AR image recognition failing to work correctly.

Figure 5. The city spaces quiz in augmented reality above the physical table markers.

3.4.2. Study 2: Workshop

This workshop took place indoors at our university campus with 4 participants, 2 men and 2 women, recruited via email. The participants were students, aged between 20 and 35, studying either computer science, architecture, or design. Each received a gift voucher as a token of our appreciation for their participation. Informed consent and image release forms were signed by all participants, and video and audio was recorded by the research team.

With all the challenges that the first study presented, it became clear that a second study was required to help gain further qualitative insights and allow for testing of the application in an indoor controlled setting. It was our aim to learn more about how participants interacted with the experiences at a qualitative level in a setting that would allow for a more focused discussion around their attitudes towards community engagement and augmented reality and allow them to test our application with support from our team in case there were any errors. The nature of Study 1 raised a few challenges and issues that Study 2 was able to compensate for. This workshop was inspired methodologically by Future Technology Workshops by Vavoula et al. [49]. In this particular methodology, the participants envisage future technologies and work backwards to co-design through current state activities. In our case, we wanted to break the pre-existing expectations surrounding augmented reality and community engagement to help them think about what community engagement could look like with this technology, rather than just what these technologies could replicate. The workshop ran in three sessions as outlined below:

- The first session ran for roughly 50 min and was strongly focused on how individuals perceived community engagement, and whether their perception of community engagement was always political. The discussion aimed to highlight the types of activities that the participants would engage with in their day-to-day life to understand what they might constitute as valid forms of participation just as much as political forms of participation.
- The second session ran for roughly 25 min and allowed each of the participants to use a tablet or phone to play with our AR experiences inside the workshop room. We had prepared each of the experiences on a separate table, and otherwise provided little instruction for the participants. We were particularly curious to see their entire interaction with the applications, from whether they would be able to understand and use them to their feedback and experience with them.
- After this, in the third session, we reconvened for a discussion surrounding the application to understand the participants experiences with the AR experiences, their attitudes towards them, and their thoughts on how or if they could be applied in a future community engagement context.

Figure 6. The city portal.

3.5. Analysis

Our research approach utilized both quantitative and qualitative methods. Our application can record all the choices that the user makes within. With the users' consent, we were able to record how they interact with each experience, the choices they make within that experience, and their total time spent in each experience. This provides us with an interesting quantitative picture, which was particularly useful in our first study when interviews were limited.

In the second study, we recorded the audio of each of the discussions as well as the video and photography of the participants' usage of our application. We attempted to use Dragon software to later transcribe the audio; however, the audio files failed to be recognized, so we transcribed the discussions ourselves. Of these discussions, we first read through the transcriptions separately, identifying some of our own perceptions of the

data. We later had meetings to discuss our thoughts between authors as to the types of comments that had emerged from the transcriptions. Following this, we entered a more formal coding phase, reviewing the entire transcriptions multiple times to identify potential emerging themes.

4. Results and Findings

4.1. Curiocity Festival

Of the data collected, we recorded 206 total city builder choices and users entered a part of the city at the street view level 277 times. The average length of time users spent playing with the city builder was roughly 3 min. The remaining choices can be found below in Table 3.

Table 3. City builder choices.

Choice	Options	Number of Times Chosen	Most Popular
Choice 1	Standard housing	8	Highrise buildings
	Highrise buildings	15	
Choice 2	Parking lots	3	Public transport
	Public transport	19	
Choice 3	Supermarkets	5	Market stalls
	Market stalls	13	
Choice 4	Observation tower	15	Observation tower
	Stadium	3	
Choice 4	Opera house	9	Equal opera house and tourist hotel
	Tourist hotel	9	
Choice 5	Stadium	4	Gardens
	Gardens	13	

In this table, we have not included the button interactions that did not require the user to make a choice, such as the 'Lay roads', 'Public services' and 'Explore' interactions. These interactions were mandatory and required the user to press them to move onto the next part of the game.

The bridge experience was triggered 27 times and the choices were as shown in Table 4.

The city spaces quiz was triggered 29 times and received 74 separate attempts to respond to its questions. The quiz would normally end after six different questions, but sometimes users would stop early or play the quiz multiple times. We displayed photos of Brisbane at different scales to the participants and asked them to guess whether this part of the city was at car scale (a highway), human scale (a quad or public space), or a combined scale (a market stall that had overtaken a street). We then recorded their answers for each. Of the 74 separate responses, we had 34 incorrect responses and 40 correct responses.

Table 4. City builder choices.

Choice	Number of Times Selected
Bridge A	27
Bridge B	21
Bridge C	20
Bridge D	14
Bridge E	20

The final portal experience was triggered 40 times. This experience did not require any further interactions and therefore did not track any more information about the participant within the virtual environment. We simply recorded when they entered into and subsequently left the portal. The average time spent inside the virtual environment was roughly three minutes.

4.1.1. Observational Analysis

Firstly, many participants were not willing to download the application. Participants would walk past the installation or read about it, but upon realizing they needed to download an application, they would stop their engagement. In other cases, the augmented reality aspect of the application would carry perceived complexity and act as a deterrent for individuals. Two comments heard were, 'it is like the sims, except that was simple, now it's too technologically advanced', and 'maybe we will download it when we get home'. On average, roughly four to five people would walk past the exhibit each hour, but most would continue on to the next exhibit without downloading the application. Lastly, those who would interact with the installation and were happy to talk more about it were, interestingly, academics, architects, or retired couples.

Something that is perhaps not often discussed in the AR literature is the difficulty of delivering a consistent experience with the current technology, and even more so when it is setup outside and open to the public. In this scenario, the promise of using novel technology as part of a public festival to engage citizens completely blindsided us to the challenges of its successful implementation.

4.1.2. Technical Limitations

There were a few technical limitations that came with the development of this application.

Firstly, Android users had to have at least Android 8.0 or higher as the version of operating system on their device. A surprising number of devices were not compatible with this requirement, as this version of Android was only released in 2017.

Secondly, the quality of the camera on the device made a large difference as to whether it would recognize the markers in the physical space or not. Setting up this installation outdoors meant that the markers would catch a lot of sunlight. The markers were also printed on a PVC foam board so that in case of rain or intense weather, they would not warp, fade, or have the image and colors run. This board was useful in durability, but surprisingly reflective and so, in full sun, it would often reflect light back at the device's cameras. On modern smart phones this presented little issue, as the cameras on these devices are quite high quality. However, we used tablets at the exhibit to lend to users who were not interested in downloading the application, and the cameras on these tablets struggled immensely to recognize the markers in full sunlight and, as a result, users were often unable to properly start the experience.

Thirdly, application size, processing power, and overall performance were all challenges that had to be prioritized in developing an easily accessible experience. We were acutely aware that asking participants to download an application to their device would add a layer of difficulty to the experience that would result in some users not taking interest and, as a result, we aimed to keep the application size as small as possible. This meant lowering the polygon count and resolutions of many of the objects within the experience. We managed to reduce the download size to 87 mb for the entire application and by reducing some resolution sizes and polygon count, we also hoped to increase performance across varying devices. Even still, performance was widely varied between modern phones and modern tablets. Smart phones would generally run the experiences with no framerate drops, although the phones would increase in temperature considerably within just a few minutes of playing. The tablets would often experience framerate drops instantly with the city builder experience and again would overheat considerably. Sometimes this overheating would result in even more framerate drops, which would result in the camera being unable to register the marker as well and the experience would jitter in and out of frame.

Lastly, whilst not an immediate issue, the low polygon counts of the application meant that the objects in the experience were reasonably simple and restricted our choices for the city builder or bridges for experience to low polygon assets. These low-polygon assets in some ways enhanced the playful nature of the experience but may have been less conducive to a believable or meaningful tool for community engagement. It was difficult to convey a

level of weight to the users' choices and, as a result, may not have educated the user on urban planning as much as presented a simple fun experience.

4.1.3. Environmental Challenges

The festival began on 12 March 2021 and ran through till 28 March 2021. Brisbane is a sub-tropical city that tends to experience 25-degree weather for the majority of the year. March 2021 ended up being a surprisingly extreme weather period for Brisbane and, during the first two weeks of the festival, there was almost non-stop rain. This greatly limited the number of participants and really tested the durability of the installation. Daily checks were required to ensure the markers had not moved, bowed, or collected too much water. When the rain ceased, the temperatures would reach upwards of 30+ degrees and during the middle of the day, the installation was so hot that it became almost completely unfeasible to expect participants to engage with our experiences. Furthermore, the reflectiveness of the markers would often confuse the image recognition software so that the augmented reality failed to trigger or the level of glare on the screen made it near impossible to see. While the installation was open to the public for three weeks, it only became usable for a few hours a day, a few days of the week. The final challenge was COVID-19, wherein during the final week of the festival, a spike in cases swept through Brisbane, eventuating in a snap-lockdown.

4.2. Workshop Discussions

Below, we present the data from our workshops. While the data below cover a few different topics, there is an overarching discussion around agency both in an emotional sense—how the participant feels in the relationship between city and citizen—and a physical sense—how the interactions and controls provide the participant with agency in that moment.

The idea of agency was often discussed throughout the three sessions, where participants stressed the importance of feeling control, feeling heard, and feeling like their opinions were valued. Throughout the first session, there were many positive comments made about the way one council member had turned budgetary ideas for the suburb into a survey that residents could complete.

Participant A: 'I remember a petition that he put out, which was very interesting for me, he sent it out to everybody who lives in that particular ward, and at that time I was living there, and it was a budget for improving different places within west end, and we as a resident could vote, and you didn't have to be a citizen, you just had to be a resident in west end, to vote where you wanted the money to go.

I thought that was very, very interesting because it was giving me agency in places that I use temporarily, but might not use in the future, and I still got a say right now'.

Furthermore, in the second and third sessions, participants gave a lot of positive feedback towards the city builder experience purely because of the agency it offered.

Participant B: "that's why I would say the build your own city is interesting because I feel like I had a say. Right? So, I do respond by building, creating something, that means that I'm active in the sense of like having a real ownership of what the city is going to look like. So, you do have that agency over, at least you have this feeling, that you have agency, whereas, when you think about just responding or being informed, I'm not too sure to what extent you are actually engaged, or do you participate".

Participant C: 'But I did like the opportunity to simulate my different choices, like, one city looks like this, and this is the music I get, and if I cancel, what happens if I do the opposite choices and it was very different and I found it rewarding to see my options matter in the game'.

Alternatively, discussions around the design of the interface were focused on how the AR controls removed agency in a way that made the participants feel confused, or unable to see the value in AR specifically.

Participant D: 'I just don't see why you need to make it AR for that experience, because I feel like you don't have much control, I mean from taking the perspective of a gamer, you have more control in the environment that you're in, but for that one, you can't even see to read the small text. Whereas, if it wasn't in AR, you could zoom, and you have more freedom'.

Participant C: 'Why do you need to walk around? When can you just sit down and move your mouse to navigate around the environment?'

Participant A: 'When it goes to the interface, I think the written things shouldn't be with the visual, they should pop up before so that I know exactly what I'm seeing, and then I go into that interface and see it, and it should just be there as backup because it's pretty difficult to read, because it's so small'.

The above comment was in relation to our design choice to include the interface in the augmented reality experience and that the instructions were floating positioned in physical space, rather than before or after the experience as a normal digital screen.

Participant C: 'I was just thinking, I would see it as you can build your city on a desktop or normal mobile interface, and then when you want to see the city, you can portal yourself there and I think that's the only place where the AR makes sense'.

A clear challenge in using novel technologies for community engagement is designing it in such a way that the user feels they have agency even though the technology is new and potentially complex. There are many factors in the design of the interface that can have unintended consequences, regarding the attitude of the user, that can shape their attitude towards the city administration overall. In our case, placing the interface within the AR resulted in some cases where participants felt that it was intentionally designed that way to give the illusion of agency without giving agency.

In this way, the interface and interactions of digital technologies are mediums through which to convey the attitudes or relationships from one stakeholder to another.

5. Discussion

The overarching aim of this research was to understand the potential for augmented reality to improve community engagement. The way augmented reality can allow users to visualize and interact with virtual environments in physical space creates a few interesting ways for councils to present information and modify consultation methods to feel more engaging. However, perhaps more important is the way that augmented reality can afford users agency over the space they occupy. Hence, the focus should not be on augmented reality solely as a technology, but instead as a new interaction paradigm that allows citizens an embodied interaction in the context of specific place. As the related works show, there have been several studies based on visualizing future plans through AR. Our findings suggest that the way AR can situate digital information in a physical space is not just interesting for its visualization affordances, but more so for how it can empower citizens within a public space.

The popularity amongst participants for our portal and city builder experiences, supported by the discussions during our final workshop session, highlights a clear desire for agency in community engagement processes. This element of community engagement is perhaps one of the more discussed aspects of civic participation processes, where critiques of 'engagement theater' and 'degrees of tokenism' often arise [8,25,52,53]. In the recent technology-enabled participatory planning literature, it is often explored how augmented reality can be used as a tool for more immersive visualizations and information sharing regarding planning projects [4,5]. It is hoped that a result of more immersive information and visualization is improved participation, especially from younger demographics [4]. A shortcoming that is often realized in this research, however, is that ultimately the issues with engagement do not rest on the technology, but instead stem from the institutional processes. Whilst AR may offer more meaningful forms of visualization, it does not necessarily offer any more meaningful engagement because in some cases the planning processes do not actually allow for citizen input.

There is a large amount of research demonstrating the success of AR visualizations for artists and improved culture within a city [42,43]. This was further highlighted by the success of several AR art visualizations offered during the festival that our first study participated in. However, we suggest that these successes are not purely due to the novelty of overlaying digital information on the real world, but instead due to what it represents in the relationship between individuals, councils, and public space. Digital urbanism and placemaking research highlight the use of AR in 'guerilla' settings for individuals to protest within or regain ownership of a public space [54,55]. In these contexts, AR is often positively discussed due to the way it empowers individuals to place their own art or visualizations over the physical world, whereas, in top-down community engagement processes, technology is often discussed as potentially novel, but ultimately still limited by a few challenges presented by the political nature of the process or the perception of the public towards the city administration that implements it.

We find this to be especially true if AR is used to recreate existing forms of community consultation. During both our time at Curiocity festival and our workshop discussions, our least popular AR interactions were those that visualized existing digital information in physical space but did not offer any further customization or creation. Those that delivered information in one-way from the application to the users struggled to convey relevance to the participants or generate excitement from the users even with the novelties of AR. We see this as a natural extension to the sentiment in the paper by Saßmannshausen et al., where it seems that a lot of the successes found were regarding the co-design and collaboration involved with developing the AR prototypes [4]. While the AR technology helped enable interaction with a younger audience, the participatory design methodologies that were employed appear to be a key success factor in the audience responding positively to the applications [4].

5.1. Most Engaging Interaction Paradigms

We suggest that the value of AR regarding community engagement requires a re-conceptualization of its affordances. While the novelty of overlaying digital information in physical space may be useful for appealing to younger audiences [4], our findings appear to show that this holds most significance when it affords users the chance to create or have some control over the information they are experiencing. In this case, the visual and interaction affordances typical to AR seem to be most effective when they are used to afford a deeper level of agency in the user. When designing interactions for AR within community engagement, we suggest that a strong focus should first be on delivering a sense of agency or control. In the context of public space, AR can allow users to overlay digital information over a public space, allowing them agency over a public space in a way previously only possible through street-art or perhaps graffiti. This was reflected in our interviews with participants:

> "that's why I would say the build your own city is interesting because I feel like I had a say. Right? So, I do respond by building, creating something, that means that I'm active in the sense of like having a real ownership of what the city is going to look like"

A criticism often received in this context is 'why AR?'. Most users do not feel that simply overlaying digital information on the physical world really adds extra value. Instead, these interactions become valuable when they allow the user to create or act in a way that makes the digital information relevant to them as users. Out of the four interactions that we explored in AR, we found that the experiences that recreated existing council–citizen interaction paradigms were overwhelmingly the least popular. The city spaces quiz and model bridge gallery—which both used AR to visualize information—struggled to engage participants in the same way the city builder and portal did. Participants commented on the way that these experiences felt particularly 'one-way.' In these experiences, participants were able to use AR as a novel way to overlay digital information on the real world, but because they did not have any input into the creation of this information, they struggled

to see its relevance. While other research suggests that AR can be used to extend existing community engagement processes [4], our findings suggest that perhaps an extension alone is not enough if these processes do not initially afford a sense of control to the end user.

The experiences that were the most popular were those that afforded the most agency. Participants thoroughly enjoyed the city builder and portal experiences and favored less the city spaces quiz or model bridge experience. Interestingly, whilst these experiences were less relevant to the broader city in that they were not representative of future plans within Brisbane and were not visualizing photos of Brisbane's public spaces, they were much more relevant to the individual who had created them. Whilst AR certainly enabled them to visualize their city in physical space, the key information is that it was 'their' city. The level of agency over their creation continued to be a resounding positive comment.

5.2. Augmented Reality for Citizen Centered Public Space

When conceptualizing AR within processes of community engagement, it is key to consider AR not just as a technology for visualizing council-defined information, but as a way for citizens to reclaim elements of public space and a sense of agency within the broader planning discussions. This is not to negate the clear affordances of AR in situating and overlaying digital information in physical spaces to create more engaging experiences, but instead to recognize that successful citizen engagement with these tools is also closely linked to the way they allow citizens to have control over a part of the discussion and appropriate the AR tools to promote their own projects and pursue their own agenda.

By placing more emphasis on the alternative ways that augmented reality can enable agency within urban planning, then our design choices are not necessarily linked to visualization or information sharing and can begin to open up to all sorts of unique, meaningful and playful interactions. When our participants entered into the street view of the city they had created, they were more interested in sharing with each other the types of buildings that they had chosen. These low-poly buildings were not necessarily exciting to look at, but the excitement came from the conversations that were enabled because of the choices made by the participant. In this experience, AR enabled a situated platform for conversation, more so than a space for visualizing existing council plans.

Participant A: 'we're using AR and then discussing about it, you have one medium it's a conversation starter, you sit and discuss'.

Our initial research [18] aimed to explore the types of conversational platforms that AR could afford. Initially, we suggested that AR offers three affordances: (a) It could be used as a situated real-time enabler of conversation between councils and citizens; (b) it allows for visual, physical, embodied, and practical co-design, and; (c) it enables a data-driven reflection of the above processes. Our city builder concept aimed to demonstrate these three affordances in that it allowed participants to co-design their ideal city, not only through text-based interactions, but also as visual digital objects in a physical space. Using choices, we attempted to emulate the types of conversations that could be had between these two stakeholders and, lastly, by recording the data of consenting users, we were afforded a reflective quantitative picture of the conversations that had taken place. While an unintended finding was the deeper desire for agency that users discussed, we do believe that the city builder experience successfully explored what an AR platform for conversation could look like and the types of interactions that could maximize engagement from individuals. While its focus was on city building, its interaction methods demonstrated the ways that AR's visual affordances could be used to share information between stakeholders, not just about planning, but about broader city environmental or social concepts.

5.3. Challenges and Limitations

Once this deeper sense of agency is established, however, it is then difficult not to undermine it with underexplored interaction methods. Minor errors in interaction design can bleed into the users feeling of agency in such a way that their attitudes towards the entire engagement process and the technology are then tarnished. Whilst in some cases,

our participants thoroughly enjoyed the way they could move throughout physical space while inside a virtual environment, they were equally frustrated by the choices we made with interface and controls and struggled to see the value in AR as a standalone technology. It is a challenge for future research to explore how AR platforms can create a sense of agency in the citizen–council relationship and, at the same time, ensure that the methods of interaction do not undermine this feeling.

Interestingly, participants often suggested that a sole focus on AR was too strong, and that a more hybrid approach to AR should be utilized instead, using existing technologies for many aspects of the engagement process and only using AR for a particular use case where its strengths were obvious. Where we had kept our different interaction methods segmented, instead, the participants were more interested in a combination of the experiences that saw them building a city, using a portal to explore it, and using the gallery to explore the impacts of their choices.

5.4. Future Research Directions

In this way, we see AR as an extension of the number of smart-city conversational platforms that have been developing around the world. The smart city literature has noted the success of developing platforms for conversation first before large-scale implementations of technology [18,45,56]. Cities such as Amsterdam have demonstrated much greater success on a considerably smaller financial budget by developing platforms that allowed citizens, institutions, and councils to engage with each other and decide upon projects that were most important for the city [45,57]. For now, these platforms tend to exist mostly online, and once projects have been decided, then move towards physical labs and other consultation spaces.

We identified a gap in the literature for discussing AR's position in a broader set of city technology platform infrastructure. Common uses of AR focus so strongly on its ability to transform previous planning or educational activities that it is not often considered how AR can be integrated into the broad set of technologies that are already implemented in cities. As sensors, online websites, social media, and artificial intelligence are all widely researched in their implementation and interoperability for improving city maintenance, resource efficiency, or civic participation, it should be further researched where augmented reality can sit in this greater tech-stack. AR on its own may sometimes struggle to convey usefulness to individuals outside of its novelty, but perhaps, in using city-wide sensor data and artificial intelligence, AR could be used to present real-time data to individuals to enable more informed conversations.

Participant B: 'the city builder, the portal, the quiz, like the merging of these three is very useful in the sense that, and this is, I'm thinking from the perspective of, educating, making decisions, having some agency and then council getting something out of it'.

Much research has been undertaken in the past five years that investigates the idea of City as a Platform. This research often investigates the way that open data, communicative technologies, and a multistakeholder participatory approach can be used to solve new environmental, social, and economic urban challenges [48–50]. However, at this stage, the platforms and research have a strong focus on artificial intelligence and the sharing of open data and little focus on the value of augmented reality to situate or visualize this information. When AR is discussed, it is more utilized in small scale, standalone, local prototypes. An interesting avenue for future research is to understand how AR can be used as a part of the broader city platform. Where the concept of open data may only be useful to those with the knowledge to analyze and use it, perhaps AR could present this data in new, meaningful ways that encourage participation from non-technologists. Furthermore, the situated and embodied affordances of AR represented in our portal experience highlight the way that these platforms could shift from something digital and found only online, to something experienced in a physical space and interacted with by individuals in a more embodied way. For those perhaps too busy to interact with websites, surveys, and digital town halls, AR could augment the existing spaces that citizens inhabit in their day-to-day

practices, shifting engagement from something required of individual citizens to something that is instead observed by city administrations or individuals within these spaces.

6. Conclusions

Augmented reality (AR) is often considered most valuable in an urban context when it can be used to visualize future plans for the area, especially in the context of a smart city or City 4.0. The successes of most research in this area, however, tend to highlight how much enjoyment and engagement the participants have in creating and placing their own models and buildings. Our findings suggest that while the visualization novelties of AR are exciting for end users, what is most engaging is the sense of agency or control that can be found from the creation and ownership of digital content in a physical space. City 4.0 suggests that more sustainable outcomes can evolve from a digitalized connection of multiple city stakeholders. Furthermore, numerous case studies [4,20,28,29,32] demonstrate that by maximizing citizen engagement in urban processes, more sustainable solutions are generated (such as improving representation of poor communities so that they can plan their own urban futures relative to their unique social and cultural processes). When we consider AR's affordances in the relationship between citizens and city administrations, rather than just the affordances it can offer visually, we can start to understand the powerful role of AR in an urban context and the value it can bring to community engagement processes when designed correctly. Its ability to enable agency and contextualize information in an embodied and visual way can further empower citizens and improve council data and, as a result, create more equitable and sustainable outcomes for urban environments. Finally, we suggest further research is required to understand AR's role within the broader urban technological infrastructure, acting as a medium for conversation between citizens and city administrations, rather than just a visualization tool for small scale urban change.

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