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Article

Gamifying Decision Support Systems to Promote Inclusive and Engaged Urban Resilience Planning

Nathan Fox [1,*], Victoria Campbell-Arvai [2], Mark Lindquist [1], Derek Van Berkel [1], and Ramiro Serrano-Vergel [1]

[1] School for Environment and Sustainability, University of Michigan, USA
[2] Environmental Studies Program, University of Southern California, USA

* Corresponding author (foxnat@umich.edu)

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Abstract
Urban residents are often unevenly vulnerable to extreme weather and climate events due to socio-economic factors and insufficient greenspace. This can be amplified if citizens are not meaningfully consulted in the planning and design decisions, with changes to greenspace having detrimental impacts on local communities, e.g., through green gentrification. These deficiencies can be addressed through inclusive landscape-level collaborative planning and design processes, where residents are fully engaged in the co-creation of urban greenspaces. A promising way to support co-creation efforts is gamifying technology-based interactive decision support systems (DSSs). Gamification, the incorporation of video game elements or play into non-game contexts, has previously been used for DSSs in urban planning and to inform the public about the impacts of climate change. However, this has yet to combine informational goals with design-play functionality in the redesign of urban greenspaces. We conducted a review of state-of-the-art video game DSSs used for urban planning engagement and climate education. Here, we propose that gamified DSSs should incorporate educational elements about climate change alongside the interactive and engaging elements of urban planning games, particularly for real-world scenarios. This cross-disciplinary approach can facilitate improved community engagement in greenspace planning, informing design and management strategies to ensure multiple benefits for people and the environment in climate-vulnerable cities.

Keywords
climate change; decision support system; gamification; urban planning

Issue
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1. Introduction

Urban areas face unique challenges in adapting to climate change, including extreme weather events such as floods, droughts, and heatwaves (Bai et al., 2018). These extreme events can cause damage to the social, ecological, and technical aspects of cities, such as damage to the built infrastructure and harm to human health (Hobbie & Grimm, 2020). Compared to natural or rural landscapes, urban areas can be more vulnerable to these extreme weather events due to the compounding effects of the built environment and modifications to natural features. For example, impermeable surfaces can magnify flooding events, and built infrastructure with low albedo can intensify heatwaves (Hobbie & Grimm, 2020). Furthermore, climate change also poses other direct impacts on cities including the loss of biodiversity, worsening air pollution, and changes to cultural heritage and tourism, as well as the indirect effects on a city's economic productivity and competitiveness (Hunt & Watkiss, 2011).

The goal to strengthen urban resilience in the face of climate change is being addressed in many cities through proposals to increase urban green space and

tree cover (Ernstson, Barthel, et al., 2010). However, urban resilience requires more than just arbitrary management plans (e.g., inconsequential planting of trees) and any proposed adaptation measures need to involve key stakeholders, including residents, in a meaningful way (Susskind & Kim, 2021). To date, the management of urban greenspaces has been traditionally driven by top-down approaches, which stress technical expertise or bureaucratic function at the expense of meaningful input from the communities who regularly use and interact with these spaces (Huang et al., 2021). Furthermore, several barriers impede community acceptance of urban planning initiatives, including: (a) distrust in city governments, (b) lack of buy-in for recommendations from planners, (c) green gentrification, and (d) concerns about personal safety and the spillover of crime from adjacent greenspaces (Anguelovski et al., 2019; Soto et al., 2018; Weber et al., 2017). These unintended consequences of excluding community voices in the planning and management of greenspace (Carmichael & McDonough, 2018) are compounded by a lack of acknowledgment and acceptance by planning professionals of cultural and provisioning ecosystem services (McLain et al., 2014; van Berkel & Verburg, 2014). These deficits can be addressed by developing inclusive landscape-level collaborative planning and design processes that can increase multifunctionality by including community-identified values and uses in the design and configuration of urban greenspaces (Campbell-Arvai & Lindquist, 2021).

As there is a high level of complexity involved in urban planning, one way to engage residents more fully is technology-based interactive decision support systems (DSSs). In the urban planning context, DSSs are software or tools developed to help find solutions to potential conflicts or problems with proposed designs whilst educating stakeholders about the proposed solutions, impacts, and benefits in a transparent way (Schindler & Dionisio, 2021; Walling & Vaneeckhaute, 2020). Originally, such decision support relied on static image depiction and photomontage alternatives to elicit feedback and management priorities during public and stakeholder consultations (van Berkel & Verburg, 2014); more recently, promising advances have been made that offer a high level of immersion, such as immersive virtual reality (VR) systems (simulated experience delivered through head-mounted displays), 3D cave environments (immersive rooms created by projectors), and multisensory environments (immersive environments that stimulate multiple senses, e.g., visual and sound; Herbert & Chen, 2015). While systems like these offer a means to interact with simulations by looking around and moving about, they often ask stakeholders to provide opinions on a few externally generated alternatives and lack the ability for users to change or alter a design or plan.

Actively engaging the community in the design of landscapes using immersive environments can empower stakeholders to challenge the status quo and entrenched top-down processes (Lindquist & Danahy, 2006). The growing number of DSSs that include users' input have required upfront consultation, built-in flexibility, and the simplification of complex systems (e.g., using a restricted number of landscape features and functions) to enable the meaningful integration of stakeholder feedback. They often include geographic information (Omidipoor et al., 2019) for investigating spatial distribution and tradeoffs (e.g., Cerreta & De Toro, 2012) and incorporate scenario-based projections for understanding temporal dynamics and plausible outcomes (e.g., Guzman et al., 2020). However, an ever-present challenge in DSSs is gaining sufficient participation and motivation for meaningful and representative public engagement. Gamification, the incorporation of video game elements or play into non-game contexts, may overcome these two challenges by providing an engaging and motivating experience, whilst allowing for users to provide inputs and make changes in real-time (Xu et al., 2017).

Though there is no standard definition for gamification, it is recognized as a process of enriching products, services, and interactive systems with game-design elements to positively influence user motivation and enhance behavioral outcomes (Deterding et al., 2011). The term "game" is used to describe numerous activities depending on the focus of interest (Parlett, 1999). In the context of DSSs, games are generally designed following the standard approach to video game design which includes providing players with goals, constraints, payoffs, and consequences whilst including some aspect of competition, either between players or self-competition (Dempsey, 1996). Games can be further categorized as "casual games" and "serious games." Casual games are typically designed solely for entertainment purposes and are generally not considered educational, while serious games are those designed not only to entertain and engage, but to also provide training and education, or to inform policy and decision making (Poplin, 2012). Both types of games have merits and limitations in educating and engaging different audiences on the topics of sustainability and urban planning, and both can be used as a gamified DSS (Ampatzidou et al., 2018; Prandi et al., 2017). Here, a gamified DSS is any tool used to aid the decision process that includes game elements; from simple features such as rewarding competition amongst participants of a workshop with points or badges, to extensive and interactive video games that represent the real-world environment (Redondo, Zapata, et al., 2020). By incorporating gamification elements, DSSs can attract users, motivate, and sustain engagement throughout a process (Deterding et al., 2011; Kasurinen & Knutas, 2018), and increase productive output (Kim, 2017).

Previous work has used non-gamified DSSs to link climate science to urban planning or management plans, e.g., Sheppard (2005) developed photorealistic landscape visualization of areas in England under both existing conditions and potential low-carbon designs, while Baird et al. (2014) used a participatory decision-making approach to the co-management of climate change

adaptation in Canada. However, to date, there is limited application of gamification in a cross-disciplinary manner that addresses climate science in an urban planning context. This article aims to assess the current best practices for gamifying DSSs, with the results of this review informing how gamification can be used to promote inclusive and engaged urban resilience planning.

2. Methods

To assess the state of the literature on gamification, planning, and climate resilience, we carried out a systematic search for recently published articles using games in the context of urban planning and climate change mitigation. To capture the full scope of gamification studies of relevance to our focus we conducted a Scopus scholar search (www.scopus.com) using the search "TITLE-ABS-KEY((gamification OR gamified) AND ((urban PRE/1 planning) OR (climate PRE/1 change))) AND PUBYEAR > 2017." This initial search returned 66 published articles. The authors carefully read these article abstracts to determine the most relevant papers (i.e., those that referred to a named game). We also considered how these articles described audience engagement, the educational opportunities from participation, and whether the game could be used to instigate real-world changes. To ensure that we captured all relevant articles, a snowball sampling approach was used to identify additional examples of games from the reference lists of papers that met our inclusion criteria. This increased the number to 27 games for final review (Figure 1). The analysis was restricted to video game technology applied to the topics of climate change and/or urban planning, eliminating non-video games (e.g., board games) as well as review and conceptual articles, as we were aiming to include only primary references to games that have been developed.

3. Results

From the 27 games identified from our systematic literature review (see Supplementary File), we identified some key best practices for engagement, education, and applications (Table 1). However, there were few examples of gamified DSS that have as their focus inclusive and engaged urban resilience planning. While we found a similar number of games centered on either climate or urban planning (13 and 10, respectively), there were only four examples (14.8%) of gamified DSSs which included *both* urban planning and climate change/urban resilience as a thematic focus. Moreover, there was a lack of DSSs with a community design focus that would allow users to interact with and augment the private and public green spaces in their neighborhoods. The implementation of

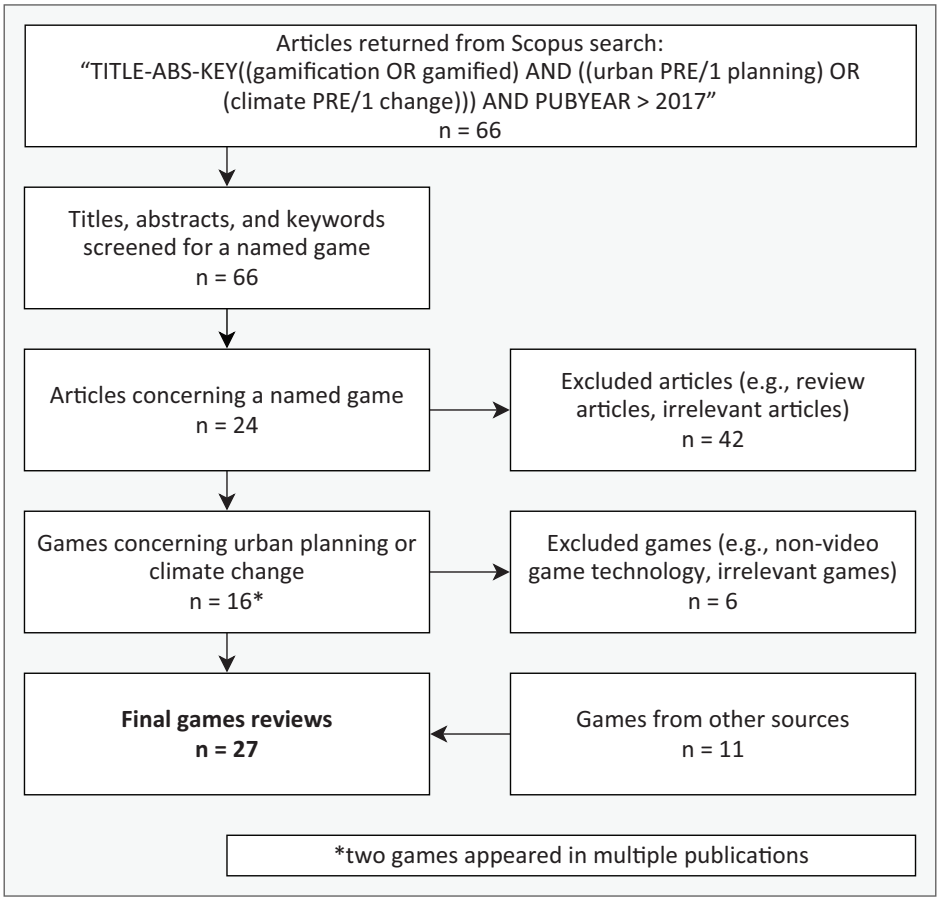

Figure 1. Systematic approach to filtering articles for review.

Table 1. Examples of best practices from reviewed games.

Aspects of Suitable Gamified DSS	Examples of Best Practices	Games
Engagement	Increased game realism	*Parkis* (Baušys et al., 2021) *Cities: Skyline*s (Khan & Zhao, 2021)
	Utilizing technology (VR or augmented reality [AR])	*GAME4CITY* (Redondo, Fonseca, et al., 2020; Redondo, Zapata, et al., 2020) *Ikigailand* (Bhardwaj et al., 2020)
	Facilitating community discussions	*Community Circles* (Thiel et al., 2019)
	Promoting continued engagement	*Land.Info* (Lindquist & Campbell-Arvai, 2021)
	Rewards-based incentives	*Cool Choices* (Ro et al., 2017)
	Diversity of participants	*Global Sustainability Crossroads* (Capellán-Pérez et al., 2019)
Education	Socialized learning	*GAIA Challenge* (Mylonas, Hofstaetter, et al., 2021; Mylonas, Paganelli, et al., 2021)
	Providing players with informed consequences of their actions	*Maladaptation Game* (Asplund et al., 2019)
Application	Designing real-world locations relevant to stakeholders	*Parkis* (Baušys et al., 2021) *Land.Info* (Lindquist & Campbell-Arvai, 2021)
	Encouraging real-world behavior change	*WasteApp* (Aguiar-Castillo et al., 2019)
	Multiple applications or scenarios	*Parkis* (Baušys et al., 2021)

these practices and examples of urban application is further explored in the Section 4. Most games assessed in this review were serious games, with only two casual games evaluated in an experimental setting.

4. Discussion

4.1. Gamification and Sustainability

Much of the gamification research to date has been in the domain of pro-environmental behavior, i.e., energy conservation, water conservation, and recycling. In these games, prizes and badges are accumulated based on "pro-environmental" behavior and goals. For example, Wemyss et al. (2018) noted a significant increase in energy savings amongst households assigned to collaborative and competitive gamified structures (vs. control households) in the *Social Power* game, and Ro et al. (2017) tested the *Cool Choices* approach to energy conservation, where individual households and teams accumulate points and prizes by adopting various pro-environmental behaviors, e.g., commuting to work by bike, replacing or eliminating inefficient household appliances, and switching to "clean energy" sources. Furthermore, Aguiar-Castillo et al. (2019) illustrated the effectiveness of the mobile phone application *WasteApp* in increasing recycling behavior amongst tourists visiting Europe. The success of these and other projects appears to be related to providing extrinsic rewards-based opportunities to learn and try out new behaviors and on the feedback provided about users' performance in comparison to set goals, or other players (Douglas & Brauer, 2021; Morganti et al., 2017).

Whilst less work has been focused on gamification to address the lack of concern and limited action on climate change amongst the public, recent reviews (Douglas & Brauer, 2021; Galeote et al., 2021) suggest that this may also be a fruitful context for application. Gamified systems, in providing opportunities for self-directed learning and skills acquisition, can build capacity and empower individuals to address climate change through their own actions and in cooperation with others (Rajanen & Rajanen, 2019). For example, *Greenify* is an online social media platform that promotes peer-to-peer learning on how lifestyle choices can affect the climate (Lee et al., 2013). Similarly, the *GAIA Challenge* (Mylonas, Hofstaetter, et al., 2021; Mylonas, Paganelli, et al., 2021) was designed for in-school sustainability education by providing a platform for cross-class participation where students compete with different schools and track progress through leaderboards. Socializing gamification, in addition to providing further motivation through interaction with peers, appears to increase climate change knowledge (including mitigation and adaptation efforts), as well as strengthening the affective (emotional) aspects of public engagement, e.g., interest, concern, personal responsibility, cooperation, and empathy (Galeote et al., 2021).

4.2. Gamification and Urban Planning

One approach to community-engaged urban planning is to stimulate community-wide discussions through rewarding participants using video game mechanics, and crowd-sourced reward tokens. Early examples that used this kind of gamification include *Community PlanIt* (Gordon & Baldwin-Philippi, 2014) and *The DuBes Game* (van Bueren et al., 2007). *Community PlanIt* (Gordon & Baldwin-Philippi, 2014) was designed to give stakeholders meaningful input to decision making, whilst providing opportunities for learning about the planning process. The game rewarded participants with points reflecting the degree to which they engaged with these community discussions. Players could then redeem their points to better advocate for the ideas they believe to be important (Gordon & Baldwin-Philippi, 2014). *The DuBes Game* (van Bueren et al., 2007) allowed for collaborative discussions surrounding the urban renewal of a fictional or real-world location. More recent games highlight how technological advancements have continued to facilitate community-engaged discussions. The app *Community Circles* (Thiel et al., 2019) facilitates communication around both bottom-up and top-down approaches to urban planning by allowing citizens to voice their own ideas about plans or issues and by providing city administrators with a platform to gauge feedback on proposals. Communication is made through geolocated posts (text, images, tags, etc.) on a map of the local community. Other users of the app can then comment on or like these posts and are rewarded with in-app points and a leaderboard that measures these contributions. Location-based games such as this can allow users to interact with and learn more about their surroundings with these interactions providing decision-makers with data on public preferences (Bishop, 2011). Single-player games can also aim to create a discussion-based atmosphere through simulated discussions via in-game characters that provide dynamic and realistic feedback on a player's choices. For example, in *MiniLautern* (Polst et al., 2021), players' actions are discussed with a fictional game narrator. Though such single-player games can help increase education and engagement, there is little scope for them to be integrated into the co-creation of climate-resilient landscapes for tackling real-world problems (Vervoort, 2019).

Some DSS games have been designed to improve communication with stakeholders on planning decisions through the simulation of proposed urban developments (Devisch et al., 2016). These games allow players to edit 3D models of urban areas with gamified goals which can be linked to realistic targets, such as tasking a player with designing a building within a fixed budget. Older games, such as *NextCampus* (Poplin, 2012), leveraged simpler 3D models to give players the ability to redesign a virtual 3D university campus within the constraints of a limited budget and in-game goals, such as improved levels of stakeholder satisfaction. More recent games build upon these concepts and provide players with additional realism and engagement through newer technologies. For example, *Parkis* (Baušys et al., 2021) generates realistic 3D models of real-world locations derived from GIS data. *GAME4City* (Fonseca et al., 2021) allows for players to interact with realistic 3D models of urban designs in a VR environment, thus providing an immersive experience in which players can gain an increased understanding of the project whilst facilitating the incorporation of user input into designs. These games can provide real-time information to stakeholders about changes in landscape features and functions throughout the redesign process (Lindquist & Campbell-Arvai, 2021). This method allows participants to view the expected visual impact of plans and allows them to indicate their preferred designs for urban spaces (Gnat et al., 2016), thus providing planners with valuable information on public preferences and improved opportunities to build public support for planning projects.

Finally, casual video games such as *Metropolis*, *Cities: Skylines*, and *SimCity* simulate the planning process putting players in charge of designing urban areas (Devisch et al., 2016; Khan & Zhao, 2021; Pramaputri & Gamal, 2019). Though these casual games can be highly engaging, they often simplify the planning process, making them less effective for educational purposes. For example, in *SimCity*, the player assumes the role of mayor of the city with the executive decision on all aspects of planning, which omits the fact that real-world urban planning requires a complex interaction between multiple stakeholders (Haahtela et al., 2015).

4.3. Challenges of Incorporating Gamification in DSSs

4.3.1. Game Design and Realism

When creating a new gamified DSS, considerations are needed for game development costs and effort, as well as how long the project will take to complete. These limitations mean that projects often face trade-offs between game design and the realism of the final product. Games relying on simple text-based designs or 2D renderings of the environment are the quickest and cheapest to develop and create (Gnat et al., 2016). Simpler 2D games can provide good representations of a city and help to facilitate education in urban planning (Poplin, 2011). However, although 2D models may be easier to create, there are multiple benefits of designing games to have a greater sense of realism. 3D models may provide an improved sense of belonging for a player (Gnat et al., 2016). Furthermore, technology such as VR and AR provides additional aspects of immersion and realism (Cirulis & Brigmanis, 2013). For example, AR games such as *The Urban CoBuilder* (Imottesjo & Kain, 2018) allows users to visualize the differences between an existing urban space and the consequences of proposed in-situ changes; this functionality may help to increase users' immersion in and connectedness to the proposals (Olszewski et al., 2017). While realistic games can be highly representative of real-world locations and

increase players' sense of connectedness to the simulated environment (Swetnam & Korenko, 2019), with the potential to increase community support and buy-in, more work is required to better understand and quantify the influence of improved realism and immersive experiences on public engagement.

4.3.2. Inclusive Gamified Systems

Previous work has shown promise that serious games can increase motivation and engagement across a range of demographics (e.g., Capellán-Pérez et al., 2019). For example, games concerning the impacts of flooding have previously appealed to wider audiences, including older adults who are less likely to play video games and teenagers who may be less likely to interact with games on serious topics (Rebolledo-Mendez et al., 2009). There are however differences in the engagement of different demographics based on the game's method of delivery, for example, a digital divide exists in which not all individuals have access to smart devices (Leuzinger et al., 2019), while older people may find VR headsets particularly challenging (Redondo, Zapata, et al., 2020). For some stakeholders, VR headsets can cause motion sickness and some challenges have been encountered in the collection of results from VR experiments (Munafo et al., 2017; Redondo, Zapata, et al., 2020). Some studies have tried to make games accessible to wider audiences; for example, Mueller et al. (2018) made their gamified system *SimUSys* available as a web-based application that requires no additional downloads. Understanding the opportunities and barriers for inclusive design and planning with diverse audiences is needed to support meaningful and sustained community collaboration. Where empirical tests of a game's behavior change and knowledge outcomes have been conducted, they have in some cases omitted diverse audiences. For example, Galeote et al. (2021) found that over half of the climate change games studies reviewed focused on primary- and secondary-aged children and that almost 80% of these studies were focused on Europe or North America. Furthermore, as ethnic, racial, and socioeconomic minorities have heretofore been offered fewer opportunities to participate in collaborative urban-focused projects, their voices are less likely to be represented in outcomes of these programs (Pandya, 2012). While gamified DSSs are highly relevant for co-creation in urban planning, there is scarce evaluation of their efficacy and inclusivity in community-based settings. There is thus a need for additional research into the use of gamified DSS for urban planning and building climate resilience, particularly to ensure that all stakeholders can meaningfully and fully engage with the process.

4.3.3. Issues of Scale

Mismatches between urban policies and environmental and social issues occur over a range of temporal, spatial, and institutional scales (Bai et al., 2018). For instance, research suggests that urban greenspace must be considered at multiple scales: from local greenspaces to city-wide networks and to the surrounding region (Ernstson, Van der Leeuw, et al., 2010). Gamified DSSs should therefore not only focus on localized urban planning decisions but ensure that they support assessment measures over the full range and extent of a decision's influence, such as how scaling-up local designs will influence regional and national environmental targets (Bai et al., 2018). Though gamified urban planning DSSs have often focused on small-scale projects, games can be applied at a variety of scales from site-specific to city-wide (Ampatzidou et al., 2018). Gamified DSSs could therefore represent the nested realities of urban policy interventions by showing scale-appropriate city- and regional-level climate targets (e.g., mitigating flooding), and performance metrics might additionally inform users of the contributions of their local designs toward these broader, landscape-level goals. Providing information about larger-scale outcomes to local users would also contribute to an improved collective awareness of landscape-scale challenges and reveal how positive outcomes can only be realized through the synergistic coordination of many small-scale design projects.

4.3.4. Reporting of Results

Many articles concerning new gamification DSSs primarily focus on describing the software and potential applications (e.g., Tóth & Poplin, 2014). However, the number of studies that present empirical tests and results for these DSSs are more limited. Where results from gamified participatory studies in urban planning have been published, they are generally framed in a positive light, e.g., increased engagement from stakeholders and positive learning outcomes (Fernandes & Aquino Junior, 2016). However, a closer reading of the outcomes of such approaches shows mixed results. For example, a comparison of traditional respondent engagement with and without gamification found no advantage to including gamified elements (Guin et al., 2012). This suggests that a more critical evaluation is necessary to assess the merits of gamification in DSSs (Hassan & Hamari, 2020). Some promising studies have begun to add these vital evaluative steps regarding the effectiveness of gamified DSSs (e.g., Redondo, Zapata, et al., 2020) by including empirical tests of games across a range of populations and end-users. Applying a more critical lens to evaluations of engagement and education potential will contribute to the growth and innovation of gamification as a DSS.

4.4. Gamified DSSs for Urban Planning and Design for Climate Resilience

To date, there has been limited application of gamified DSSs that directly engage citizens with real-world urban planning and design for climate resilience. The game

Ikigailand (Bhardwaj et al., 2020) starts to address this by placing competition between two players who test the other players' city design by subjecting it to a catastrophic event, while the *Mayor's Dilemma* (Müller et al., 2018) touches upon these themes by placing players in the role of growing a simulated city focused on different energy production methods, the choice of which has impacts on their city—e.g., amount of air pollution. However, these two games do not allow players to build realistic worlds capable of guiding real-world planning scenarios; thus, current games that acknowledge both urban planning and climate reliance tend to have limited real-world planning and design opportunities. We argue that such a gamified DSS could be improved by engaging a wider range of audiences on the multiple dimensions of urban climate resilience initiatives, promoting inclusivity, and supporting actionable citizen-engaged decision making. The success of such a tool can draw on previous experience of DSS and gamification in other contexts by leveraging different forms of motivation and social learning (Seaborn & Fels, 2015) and by incorporating design objectives that matter to local communities (Campbell-Arvai & Lindquist, 2021).

Some citizen-engaged design of cities has provided participants with limited feedback on the environmental impact of their decisions, e.g., based on the architectural design of buildings (Birch et al., 2018). However, if the feedback given to participants does not also promote learning and reflect meaningful user-generated outcomes, the utility of engaging the public in a design process may be limited (Devisch et al., 2016). Gamification and the 3D visualization of cities can provide an intuitive method for non-experts to explore spatial designs and can provide real-time multicriteria feedback based on users' design decisions (e.g., costs, rainwater storage; Bishop & Stock, 2010). Games that facilitate community deliberation and collaboration, such as through online or in-person fora (e.g., Gordon & Baldwin-Philippi, 2014), additionally allow for participants to learn from the viewpoints and designs of others, providing them with opportunities to gain a broader and deeper understanding of the topics and design opportunities at hand (Latifi et al., 2020). Furthermore, through an inclusive collaborative planning and design process, the process of co-production can increase multifunctionality by including community-identified values and uses in the design and configuration of urban spaces at multiple scales.

Based on our previous experience with the DSS *Land.Info* (Campbell-Arvai & Lindquist, 2021; Lindquist & Campbell-Arvai, 2021), we believe that such systems can allow for user-generated climate-resilient designs for urban greenspace and green infrastructure by placing users in simulations of their community and casting them in the role of a landscape designer. Whilst designing their landscapes, users can be provided feedback about key performance metrics so that they may evaluate the impact of their designs against scale-appropriate climate resilience targets (e.g., mitigating flooding, reducing urban heat island effects), as well as other objectives of relevance to residents (e.g., aesthetics, personal safety, and recreation opportunities) that have often been ignored in expert-driven top-down design processes. Furthermore, design-scale DSSs like *Land.Info* can build community knowledge and buy-in through engaging participants in workshops and design charrettes, online and in-person. Evaluation of learning outcomes from and user satisfaction with such inclusive design processes is ongoing.

The lessons from our literature review suggest that the success of a gamified DSS for urban planning and climate resilience requires elements that promote engagement, facilitate education, and that the system is applicable to the real-world challenges of users (Figure 2). To be successful, DSSs need to provide an engaging experience for citizens. As traditional forms of civic participation, such as polls and consultations, do not lend themselves to promoting long-term sustainable engagement, interactive games can provide learning opportunities for individuals and communities that foster continuous engagement in urban planning (Devisch et al., 2016; Gordon & Baldwin-Philippi, 2014). Additionally, through providing an alternative educational approach and learning model, DSSs can be uniquely suited to address knowledge deficits, create buy-in, break ingrained habits, and increase long-term engagement (Devisch et al., 2016; Galeote et al., 2021; Petersen et al., 2019; Ro et al., 2017). Finally, games should have real-world applications that can have beneficial impacts on local communities (Baušys et al., 2021; Lindquist & Campbell-Arvai, 2021). A good balance of these qualities is likely to enhance user experiences by improving motivation for participation and offering an understanding of the implications, both positive and negative, of a proposed design.

Adding gamified elements to design-scale DSSs can play a key role in motivating participation and supporting learning, e.g., about the multifunctionality of public greenspace and the climate resiliency benefits that can accrue (Bonney et al., 2009; Silvertown, 2009). Public visibility of gamified outcomes may increase individual-level motivation for participation through the prospect of influencing local outcomes and foster long-term community-level involvement in the achievement of community-identified climate resilience targets (Kasurinen & Knutas, 2018; Newman et al., 2012). Such increased public participation may additionally encourage traditional public and private entities like municipal planning departments to incorporate suggestions from citizen inputs (e.g., crowdsourcing). Moreover, gamification can reduce the common challenges that planners have in attracting broad participation and citizen feedback by removing barriers to citizen involvement. New voices can be heard when time constraints are removed (e.g., public fora are held digitally rather than in-person) and real-world benefits are realized (e.g., community feedback is integrated into the planning process). Social interaction in such systems has the potential to mobilize

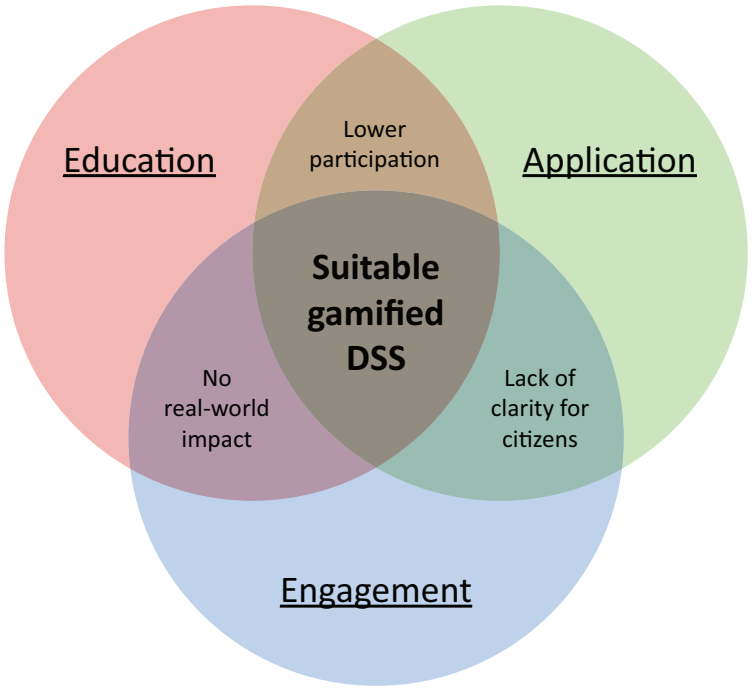

Figure 2. The engagement, education, and application framework for gamified DSSs.

a diversity of citizens in collective action and contribute to the democratization of the planning process in the service of inclusive and resilient cities (Afzalan & Muller, 2018).

4.5. The Future of Gamified DSS Under a Changing Climate

The development of inclusive technologies means that the accessibility of these games will increase. It is now possible to disseminate "high-tech" games, such as those using AR, to people through their mobile devices, allowing play from home or on the move (Mühlhaus et al., 2018). These emerging technologies can not only increase the number of people that can participate in crowdsourcing data, but also open novel and broad-based opportunities for climate resilience planning.

4.5.1. Future Technological Developments

Emerging technologies may help to further refine the public engagement, education, and planning applications of DSSs. For example, deep learning-based image interpretation can be used to infer user landscape preferences from choices made during the DSS design process, e.g., the influence of vegetation types and landscape complexity on aesthetic preferences (Gosal & Ziv, 2020; Havinga et al., 2021). Machine learning technologies, such as the Google Vision Cloud API and the Clarifai AI, have previously been used to assess photographs of landscapes and urban areas in a range of planning contexts (Ghermandi et al., 2022). It is foreseeable that these algorithms can be applied to photorealistic designs generated within video game DSSs to provide a more standardized evaluation of citizen designs to aid in supporting decisions, i.e., the degree to which they meet aesthetic, recreational, or carbon capture goals. The ability to identify favoured landscape features and functions will not only provide insight into landscape preferences but will also bolster our ability to identify landscape designs that optimize public use and multifunctionality, e.g., balancing needs related to human well-being and stormwater management (Rai et al., 2019). Furthermore, AI algorithms can utilize other datasets such as light detection and ranging (LiDAR) for landscape-scale disaster management such as simulating fire in a gamified environment (Yu et al., 2021).

As a result of climate change, game designs and, in particular, the generation of realistic 3D environments, will need to rapidly adapt to emerging challenges and constraints. However, current methods of generating 3D models of cities usually require time-consuming manual methods (Gnat et al., 2016). As urban areas become more prone to natural hazards, such as flooding and extreme weather, these 3D models must have the capacity to autonomously update to rapidly reflect changing landscapes, climate threats, and user needs. To meet these emerging needs, DSSs should leverage automated 3D model generation to quickly update features. For example, 3D point clouds from remotely sensed LiDAR data can be a useful tool for generating 3D models representing changing landscapes (Spielhofer et al., 2017).

4.5.2. Novel Applications

Climatic change is already having considerable impacts on cities and, as such, it is likely that DSSs will be a

valuable tool for addressing these shifts. Future systems should be designed to address the rapidity and nonlinearity of climate change with built-in flexibility that can help developers react to new community needs and reflect changes in real-time. Such flexible platforms can strengthen community resilience by structuring discussion about stressors and aid in preparedness, for example, by providing neighborhood-level climate information and serving as a platform to pinpoint locations for intervention prioritization and as fora for reporting on and learning about climate-related disasters (Kankanamge et al., 2020). Games focusing on emergency planning, such as *Ready!* (van den Homberg et al., 2015) tend to focus on the community capacity to respond to disasters; however, these games could be reoriented to increase policymaker emergency planning foresight, as demonstrated by *WeShareIt* (Onencan et al., 2016).

Gamified DSS can contribute to smart cities by leveraging interconnectedness and big data to improve the livelihood of citizens and overcome complex challenges such as climate change. Here, gamification can be used to enable citizens to voice their opinions and concerns about smart city designs and help practitioners better respond to the needs and concerns of residents (Latifi et al., 2020; Zica et al., 2018). Furthermore, gamified apps can enable citizens to contribute to the large datasets that drive smart cities, such as recording and uploading water or soil quality (Bucchiarone et al., 2021). There is also scope for casual games to be a useful tool in the planning of sustainable cities. For example, a recent update to *Cities: Skylines* allows players to focus on sustainable development and could be useful for crowdsourcing experimental smart city designs from citizens (Khan & Zhao, 2021).

5. Conclusion

The goal of this article was to assess the current best practices for gamifying DSSs and to inform how gamification can be used for community-engaged landscape design to tackle climate change adaptation in climate-vulnerable cities. Here, we have identified three core principles that DSSs should follow: engage a larger number and diversity of stakeholders; educate participants about the positive and negative outcomes of design choices and scenarios; and be grounded in real-world applications. Gamified DSSs should therefore present opportunities to not only engage and educate citizens on the serious topics of climate change and urban planning but facilitate actual community-driven changes to urban and landscape plans. As a departure from expert-driven top-down management, a community-based and collaborative approach to landscape design will allow us to learn more about the community members' preferences and help to foster long-term community-engaged and resilient landscape designs in the face of climate change. Here, we have highlighted several research gaps that may limit the effective application of gamified DSSs in influencing decision-making. Combining informational goals with design-play functionality in the redesign of urban greenspaces will add novel urban planning engagement and climate education tools to the burgeoning DSS game space. Moreover, empirical work should be undertaken to assess the effectiveness of different gamification elements to improve the diversity of stakeholder engagement, and to ensure that the results of gamification studies inform the urban planning process. Including the public in such exercises must be part of larger strategies aimed at changing public attitudes, inspiring public action, and democratizing the urban planning and policy development process.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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About the Authors

Nathan Fox (PhD) is a multidisciplinary researcher focusing on the complex human-nature relationships that govern the benefits we receive from the environment. His research utilizes novel citizen sourced datasets including the use of big data from social media to assess human-nature relationships, and how gamification can facilitate citizen participation in environmental planning. Nathan's work carries the underlying ethos that open-source software and collaborative approaches provide the best opportunities for maximising benefits for people and the environment.

Victoria Campbell-Arvai (PhD) is an interdisciplinary social scientist who seeks to explore theoretically interesting questions with an applied twist. Her research focuses on how people do (and do not) use information to form judgments, make decisions, and adopt environmentally significant behaviors. She uses mixed methods to explore these questions (surveys, survey-based experiments, focus groups, and interviews), as well as through community-engaged participatory research. Dr. Campbell-Arvai's main research contexts are food, energy and climate, and urban ecosystems.

Mark Lindquist's research and teaching focus on the design and evaluation of high-performance landscapes with an emphasis on multifunctional green infrastructure in urban areas. He is particularly interested in understanding how engaging with computation, data, virtual and augmented reality can transform the design process and inform decision-making by stakeholders. Mark uses video game technology and conducts empirical research with the aim of providing an evidence base to support the design and planning of environments that perform ecologically, socially, and culturally for more sustainable outcomes.

Derek Van Berkel is assistant professor of data science, geovisualization and design. His research examines the human dimensions of land-cover/land-use change and ecosystem services at diverse scales. It aims to use spatial analysis and geovisualizations of social and environmental data and spatial thinking to develop solutions for today's most pressing environmental challenges. Within this growing body of interdisciplinary work, he leverages social theory, big data, machine learning, spatial-temporal computer modeling (e.g., agent-based and cellular automata), and spatial statistics.

Ramiro Serrano-Vergel, associated researcher, is working on how gamification can facilitate citizen participation in environmental planning. His PhD is in information science and his Master's degree is in systems and computing engineering. Vergel's research addresses augmented and virtual reality and the development of interactive graphical applications based on the cross-platform game engine Unity3D. His applied perspective focuses on the design and conception of new solutions based on an immersive and interactive visualization of massive data contexts.