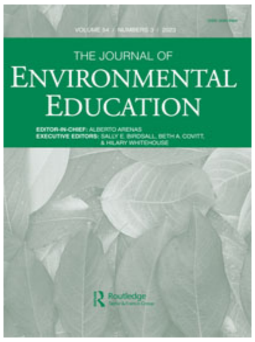

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RESEARCH ARTICLE

Designing *Chill City*: An interactive game supporting public learning about urban planning for extreme heat

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ABSTRACT

Climate change and the urban heat island (UHI) effect are increasing extreme heat risk in cities across the world, and have already made extreme heat the top weather-related cause of death in the United States. Despite this, understanding of viable strategies to address extreme heat is still limited, for both decision-makers and the public. Using a design-based research methodology, we developed an interactive educational game, *Chill City*, which teaches players about possible heat planning strategies and their tradeoffs. We surveyed adult, non-expert players to understand the game's reception and impacts. Players expressed that they enjoyed the game and that it helped them better understand heat planning strategies and the environmental, social, and economic tradeoffs associated with them. We argue that environmental games offer educational potential for adult learners on issues of extreme heat and climate change that should be further explored to inform effective approaches and designs.

KEYWORDS
design; games; urban planning; urban heat island; extreme heat; adult learning

Introduction & literature review

Extreme heat is an increasing hazard in cities across the world due to climate change and the urban heat island (UHI) effect. Temperatures have risen 1.8 °F (1 °C) in the contiguous United States since 1900 and are projected to rise by as much as 12 °F (6.7 °C) by 2100 under the highest projected greenhouse gas emissions scenarios (Hayhoe et al., 2018). Extreme heat events are increasing in frequency, duration, and intensity due to climate change, occurring on average six times per year during the 2010s compared with two times per year during the 1960s (EPA., 2021). This is compounded by the UHI effect, which leads to urban temperatures that are higher than rural and natural area temperatures by as much as 7.2 °F (4 °C) during the day and 4.5 °F (2.5 °C) at night due to the design of the built environment and associated building and vehicle waste heat (Hibbard et al., 2017; Oke, 1982; Stone & Rodgers, 2001). Extreme heat is the top weather-related cause of death in the United States (Hondula et al., 2015), and also increases energy and water use (Grimm et al., 2008; Guhathakurta & Gober, 2007), degrades infrastructure, decreases economic productivity (Watts et al., 2018), and harms urban vegetation and wildlife (Brans et al., 2018). Vulnerable communities are particularly at risk for heat-related health impacts (Kovats & Hajat, 2008), making it a social justice issue. In sum, extreme heat causes additional stress to urban ecosystems (Merckx et al., 2018) and threatens the viability of cities (Pal & Eltahir, 2016).

Despite these well-documented impacts, heat planning and governance is still in its infancy compared to planning for other climate hazards such as flooding, sea level rise, drought, and wildfire (Keith et al., 2019; 2021; Koop et al., 2017). An assessment of over 3,500 climate adaptation resources in the United States found that only 4% focused specifically on heat (Nordgren et al., 2016). Mahlkow and Donner

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(2017) observed that "only recently has the scientific community given more attention to the way planners and policymakers perceive and deal with the particular climate change adaptation issue of urban heat" (p. 385). In a survey of U.S. planners by Meerow and Keith (2022), 84% of planners reported that their community had already been impacted by extreme heat and 87% indicated using at least one strategy to address it. These strategies include heat mitigation, or efforts to decrease the urban heat island effect, and heat management, efforts to prepare and respond to acute and chronic heat risk (Keith et al., 2021). Urban greening strategies, such as increasing urban forestry and green stormwater infrastructure, are currently the most popular form of heat mitigation, while other strategies such as land use and development regulations, urban design, and waste heat reduction are less commonly used (Meerow & Keith, 2022). Heat management strategies include emergency response coordination, cooling centers, and public awareness and education campaigns (Meerow & Keith, 2022).

Top-down planning and design strategies for extreme heat are often not given priority over other community values, such as esthetics (Hatuka & Saaroni, 2014). Key barriers to planning for heat include competing priorities, insufficient resources, and weak leadership and public support (Meerow & Keith, 2022). Another challenge is framing extreme heat and communicating this risk to the public because heat is, "an outlier hazard—invisible, frequently chronic and subtly pervasive," (Keith et al., 2021, p. 29). Heat impacts are less visible than those from more dramatic events like wildfires or flooding, and those most impacted are often communities and individuals who are marginalized from local decision-making processes (Keith et al., 2021). These gaps in public knowledge pose a significant challenge in democratic settings where citizens influence the policymaking process. Without an informed public, difficult decisions about mitigation and adaptation strategies can become politically impracticable (e.g., Callison, 2014).

One critical element in advancing efforts to address extreme heat is environmental education. Where the lack of climate knowledge was once seen as the primary issue in climate-related education (Ouariachi et al., 2018), scholars have also noted problems in how information is conveyed, such as the need for participatory, multimodal, empowering, and interactive communication (Cooper, 2011; Moser & Dilling, 2011). Similarly, negatively framed climate communication, which can dominate media and education spaces, has complex effects on behavior and may lead to inaction without commensurate, actionable information on how to respond to climate risks (Bloodhart et al., 2019; Brosch, 2021).

Games are increasingly being posed as one potential remedy to these issues, making space for learning about climate risks in an interactive, participatory, and solutions-focused format (Reckien & Eisenack, 2013; Wu & Lee, 2015), and helping players gain basic climate literacy (Fung et al., 2015; Harker-Schuch et al., 2020). Students may be involved in not only playing games, but developing them, creating opportunities to explore climate issues in relation to problem solving and computational thinking (Tucker-Raymond et al., 2019). Games can be used to help players reach common consensus on climate-related goals (Ouariachi et al., 2018), and can allow players to grapple with complexity and tradeoffs in potential climate mitigation policies (Neset et al., 2020; Van Pelt et al., 2015). Even games that are not explicitly about climate issues can have positive effects by including settings, esthetics, and world building that implicitly convey potential climate futures (Abraham, 2018). The immersive quality of games' visualizations of climate change impacts and mitigation strategies can be an especially effective tool for educating and engaging the public (Sheppard, 2012).

The underlying logic behind game construction and play in relation to issues of cooperation and competition may play a key role in why games are such effective learning tools. Game theory has been identified as an important tool for developing climate change policies that are sensitive to the complexities of cooperation and collective action within and across nations (Buck et al., 2021; Carfí et al., 2021; Cramton & Stoft, 2012; Hasson et al., 2010; Hurlstone et al., 2020; Jacquet et al., 2013; Lenton, 2014; Tollefson, 2008; Wood, 2011).

Beyond climate-related issues, games have also been identified as a way to address contentious political debates within democratic societies. Lerner (2014) argues that participatory democratic practices work best when they take on game-like features such as clear rules, defined competition, and measurable outcomes. Games can help community members play out scenarios and make decisions about the future (Domsch, 2013). Games have been noted in their use for urban contexts, such as smart cities, participatory urban planning process, and learning (Crisman et al., 2020). Marketing research has demonstrated the difficulty for consumers in decisions that require evaluation of tradeoffs (Luce et al., 1999; Wang et al., 2010), but understanding such tradeoffs is essential for climate education (Galafassi et al., 2017) and enabled through game-based learning. The pedagogical affordances of games, especially in relation to digital interactive games on climate-related issues, suggests that games could offer an effective mechanism for exploration of such tradeoffs (Sheppard, 2012).

Having access to accurate and comprehensive information is central not only for expert policymakers, but also for lay publics who participate in democratic processes (Fishkin, 1991). Climate games, then, can educate about climate-related issues and, by doing so, provide support for democratic processes, consequently increasing likelihood of political acceptance for climate policies (Driscoll & Lehmann, 2015; Schenk & Susskind, 2015). As Schenk and Susskind (2015, p. 159) have noted, game playing learners "do not just increase their own understanding" but also "increase their appreciation for the multifaceted nature of decision making in complex environments, and thus their ability to work with other stakeholders to enhance resilience and address vulnerabilities." We hypothesize, then, that a well-designed educational game about extreme heat for adult learners can provide significant benefits to public learning about this poorly understood climate risk and, by extension, open windows of political possibility through public acceptance of necessary climate change adaptation policies.

While a wide range of climate change-related games have been developed, there remain a number of gaps in the kinds of games produced and the potential impacts that games might have on climate change mitigation efforts (Gerber et al., 2021). Many climate games have focused on reduction of carbon emissions, while fewer have dealt explicitly with mitigating heat. Additionally, most climate games examined in the literature focus either on *educational games* for K-12 students or on *serious games* meant to help professionals problem-solve (e.g., Rodela et al., 2019). Only more recently has there been a focus on educational games for lifelong learning among a broader public (Romero et al., 2017).

We ask, accordingly, what design elements are required within an educational game about extreme heat to support players in increasing their understanding of climate risk, and by extension their acceptance of heat planning policies? To answer this question, we use a design-based research methodology. In this article, we first explain how we approach the use of design-based research, including the design process for a game titled *Chill City*, and our methodology for its subsequent testing against our hypothesis. Next, we present our findings from this methodology, focused especially on the promising qualitative findings that came out of a survey we administered to game players. Finally, we conclude with a discussion on the potential that educational games hold for learning about extreme heat and its related mitigation strategies which we find to be promising and worth further research given our study's limitations.

Methodology

In this study, we used a design-based research methodology, or the design and development of an intervention, and then the testing of that intervention, which can then be used to iteratively modify and re-test (see, e.g., Philippakos et al., 2021). Design research within educational research was developed in response to the need to study pedagogical designs and interventions within their real-world environments, including complex situations with multiple dynamic variables (Brown, 1992; Collins, 1992). Design research, in contrast to typical controlled laboratory experimentation, is typified by real-world settings, multiple variables, flexible design revision, social interaction, and, rather than aiming to control variables and test a hypothesis, instead aiming to characterize an overall situation and design profile in practice (Collins et al., 2004).

While scholars in education use design research, the theoretical underpinnings come from design theory and the history of science, contrasting design sciences with natural sciences (Simon, 1969), and developing procedures to grapple with "wicked problems"—typified by a lack of a clear definition or well-defined goal, by qualitative evaluation on a continuum rather than black and white tests, and by the essential uniqueness of the problem that makes learning and comparison difficult (Rittel & Webber, 1973). These qualities describe the messy, real-world difficulties of designing not only educational interventions, but also climate mitigation interventions, and, in our case, their intersection.

Our design-based research design is as follows. Our intervention was an online game about extreme heat that we designed as an interactive environmental educational tool titled *Chill City.* Participation involved the real-world experience of using this web-based, interactive learning game. Users were provided the game, which included simple embedded instructions, but were not given additional hands-on training or in-person guidance on how to play or what they should be learning. We surveyed players before and after gameplay and collected qualitative and quantitative data on their reception of the game, learning related to extreme heat, and attitudes toward climate change adaptation. Our study followed guidelines for ethical conduct of research, including review and approval by an Institutional Review Board, and we have included our survey instrument as an appendix to this article.

Our design research process, therefore, was not only one of educational design research seeking to interrogate the game as a learning tool, but also one that provided feedback into the iterative design process of developing the game, including the content of included climate interventions, visualizations of those interventions, and underlying structure for gameplay. Feedback criteria included two key gameplay elements established as important for effective game design by game studies scholars. First, the game should produce "flow," or full immersion within the game due to strong usability, clear goals, and fast feedback (Csikszentmihalyi, 1990; Kiili, 2005). Second, the game should generate "pleasurable frustration," or a balancing of challenges to be exciting and achievable yet also difficult (Annetta, 2010; Gee, 2004). Gee (2004) describes pleasurable frustration as an element of learning where players gain mastery of increasingly difficult skills and knowledge. This pleasurable frustration extends out of a key pedagogical goal of the game, which is to provide an interactive demonstration to learners about the tradeoffs inherent to all climate change adaptation strategies. Annetta et al. (2011) ultimately connect these two elements by observing that "players will reach pleasurable frustration if flow is held for a sustainable time period" (p. 79). We follow this linked logic in our design research for *Chill City*, which suggests that we should interpret game feedback that positively reflects on extended play and/or learning as indicative of both flow and pleasurable frustration.

In addition to the elements of flow and pleasurable frustration, the game design can also be considered through our attempts to balance preferences, including coherence, complexity, legibility, and mystery (Kaplan & Kaplan, 1983). The game design coherence includes the ease of which the gameplay and interface can be understood, while the complexity includes the variety and richness of gameplay objects (Kaplan & Kaplan, 1983). Legbility includes the ease of orientation toward achieving the gameplay goals (Kaplan & Kaplan, 1983). The preference of mystery has the aim of sustaining interest through the game (Kaplan & Kaplan, 1983). We hypothesized an appropriate level of gameplay frustration through a balance of these preferences would help better facilitate player learning objectives of understanding extreme heat planning strategies and their tradeoffs, and thus we iteratively modified elements of the game's design to achieve this prefence balancing outcome.

Chill City game design process

The first phase of game design and development focused on exploring the various heat planning strategies available to urban environments. Through reviewing the literature on heat planning strategies, we identified the following strategies as worth including based on robust evidence for each from three or more sources: cool roofs and walls; green roofs and walls; waste heat reduction; urban tree canopy; shade structures; public park space; public water features; green infrastructure; drinking water fountains; cool pavement; cooling centers; and public education and communication (see Appendix A). Note that not all strategies are described in the literature as effective. For example, evidence suggests green roofs and walls do not always live up to their publicized appeal or high cost (Farrell et al., 2012). We therefore set goals for learning outcomes that included an understanding of both the potential affordances and weaknesses of extreme heat mitigation strategies based on the evidence, emphasizing the tradeoffs associated with each.

To balance the gameplay aspects of coherence and complexity while facilitating the flow state and pleasurable frustration qualities of effective games, we combined the many different specific tradeoffs associated with each heat planning strategy into three categories: cost or resources required, positive social impacts (e.g., positive health effects), and positive environmental impacts (e.g., limiting unnecessary consumption of water resources).

We then used an inter-rater reliability scoring process (see Armstrong et al., 1997). Four raters independently scored each strategy from zero to three for social and environmental impacts based on evidence in the literature, with zero meaning no impact and three being a significant combination of multiple impacts. We also scored the cost of each strategy relative to one another on a scale from zero to 200 to eliminate the problems of using a real dollar amount (e.g., inflation over time, differing costs by geography). We determined during the scoring process that scores were dependent on knowing which type of climate a strategy was used in: hot and dry, hot and humid, or temperate. These three climate zones then became three variations of the "game board" so that players could explore the complex interactions between strategies and climate types. We undertook four iterations of independent scoring, followed by discussing similarities and differences until the scores from the four raters were harmonized and finalized.

While the primary objective of this process was to provide a rigorous scoring system for the tradeoff numbers underlying the game logic, the scoring system is also useful for informing players' understanding of the various heat planning strategies available today, including their relative impacts, costs, and tradeoffs (see Table 1). We incorporated into the game qualitative descriptions of impacts, an accessible explanation of the strategy, and noted the location of where each strategy would occur: in open public space, within street space, in or on public buildings, or within private buildings. Since the scale of strategy is smaller at the level of a private building compared with a public space, private building strategy scores were divided by a factor of five. The game board that players view as they choose strategies shows a "small town Main Street condition" (Figure 1)—a street with landscaping reflecting the climatic zone, public buildings on one edge, five private buildings on another edge, and a public space in the center (which begins as a parking lot). This Main Street design was selected to maximize both coherence and legibility for players.

The basic gameplay of *Chill City* unfolds as follows.[1] First, a player opens the game to a decision screen where they must select a climatic zone for their game board (Figure 2). When the chosen game board

Table 1. Scoring and design for extreme heat mitigation strategies in Chill City.

Intervention	Game Location	Game Visualization	Social*			Environmental*			Relative Cost
			HD	HH	T	HD	HH	T	
Cool roofs and walls	Private buildings	Roof and walls of private building turns to light color (can implement multiple times; conflicts with green roofs and walls)	0.4	0.4	0.4	0.2	0.2	0.2	15
Green roofs and walls	Private buildings	Roof and walls of private building become planted (can implement multiple times; conflicts with cool roofs and walls)	0	0.2	0.2	0.4	0.2	0.2	100
Waste heat reduction	Private buildings	HVAC on roof of private building turns sci-fi looking (can implement multiple times)	0.2	0.2	0.2	0.4	0.4	0.4	20
Urban tree canopy	Private buildings	Additional tree is planted in front of private building (can implement multiple times)	0.6	0.6	0.6	0.2	0.4	0.4	15
Shade structures	Private buildings	Awnings are inserted in front of private building (can implement multiple times)	0.6	0.6	0.6	0	0	0	10
Urban park	Open area	Parking lot turns into park	3	3	3	3	3	3	200
Water features	Open area	Splash pad and misters are added to park	2	1	2	2	0	0	200
Green infrastructure	Street	Street curb cutouts along entire street with plantings	2	2	2	3	3	3	150
Drinking water	Street	Drinking fountains are installed along street	1	1	1	0	0	0	30
Cool pavement	Street	Light colored and pervious paving replaces existing street	1	2	2	1	2	2	50
Cooling centers	Town hall	Cooling center sign goes up on town hall	1	1	1	0	0	0	0
Public education and communication	Town hall	Heat warning billboard goes up on town hall	1	1	1	0	0	0	5

*Social and environmental impacts are scored separately for hot and dry (HD), hot and humid (HH), and temperate climatic zones.

Figure 1. The "small town Main Street condition" of the Chill City game board.

Figure 2. Initial menu where the player must select a game board based on climatic zone.

then opens, an informational window pops up that explains how to play the game and provides a basic explanation of the importance of grappling with extreme heat (Figure 3). The player can then cycle through a learning module on each of the strategies, which includes where they are installed on the game board and their relative cost on a scale of one to four dollar signs (Figure 4).

The player can then drag any of the strategies onto the game board to see what kind of impacts they have on different areas, such as the urban park, which requires a large number of resources but has significant positive social and environmental impacts (Figure 5). The process of strategy experimentation by players was included to achieve an appropriate level of gameplay complexity. In addition to the scored impacts, we also incorporated a qualitative set of "outcome badges" that describe the specific benefits of a particular strategy, such as "improving air quality." These benefits were based on the literature review and provided an additional learning opportunity as a "side quest" to the primary goal of winning the game.

The player is encouraged to test numerous combinations of strategies to understand tradeoffs and the nature of finite resources and capacity limitations (Kaplan & Kaplan, 1983) and can remove a strategy with the bulldozer at any time. As they achieve a combination of social and environmental impacts, the main temperature thermometer to the right of the screen drops until the player reaches their target "chill"

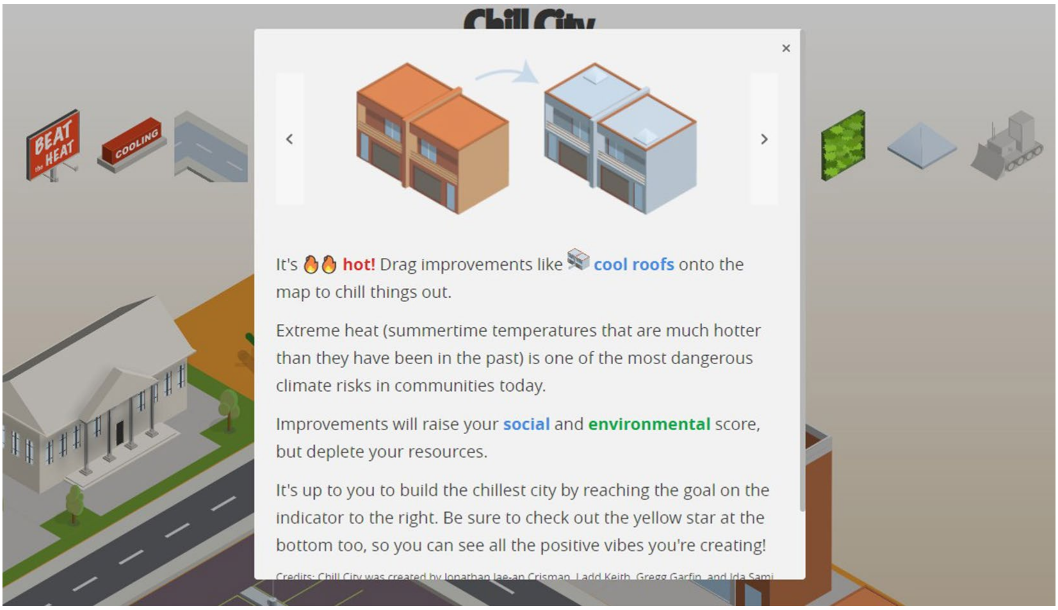

Figure 3. Informational pop-up when the game board first opens, explaining how to play the game and the importance of grappling with extreme heat.

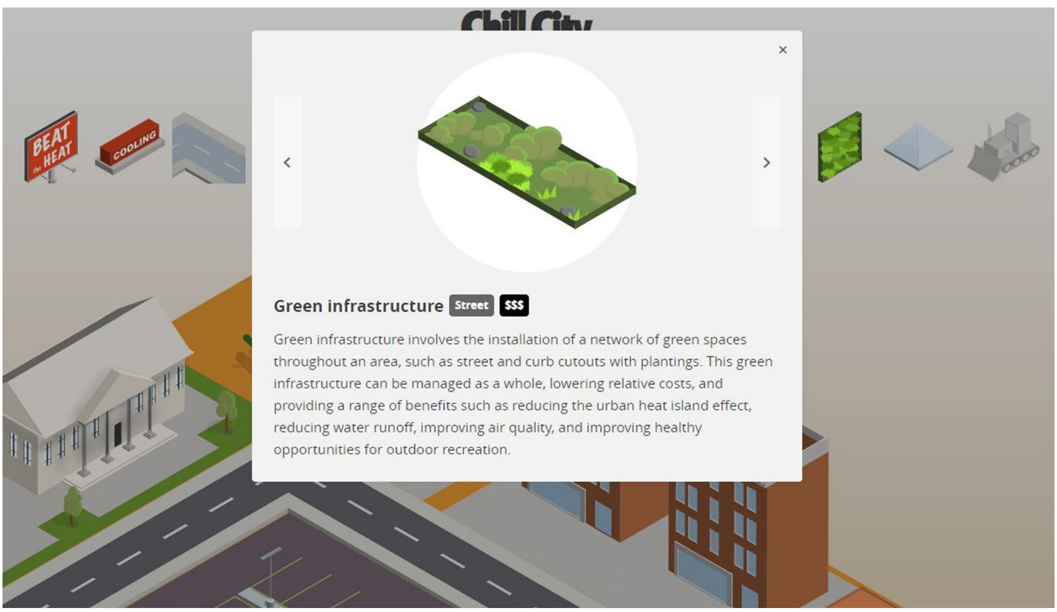

Figure 4. Learning modules on each of the extreme heat interventions.

temperature and "wins" the game (Figure 6)—winning can happen through several different combinations of strategy use. The player's preferred combination of strategies is saved through a custom link that is generated and allows them (or their friends, if shared) to return to the game board as they left it.

Based on user feedback from successive iterations of the design-based research process as well as internal feedback from our research team's gameplay testing, we refined the strategy logos and "drag and drop" gameplay process to make the game flow better and work more intuitively for gameplay legibility. We also made the informational pop-up windows a central element of the game for gameplay coherence, rather than an optional and less prominent element, as we identified these as critical components for

Figure 5. The game play in action as interventions are dragged onto the game board, resulting in environmental, social, and resource impacts.

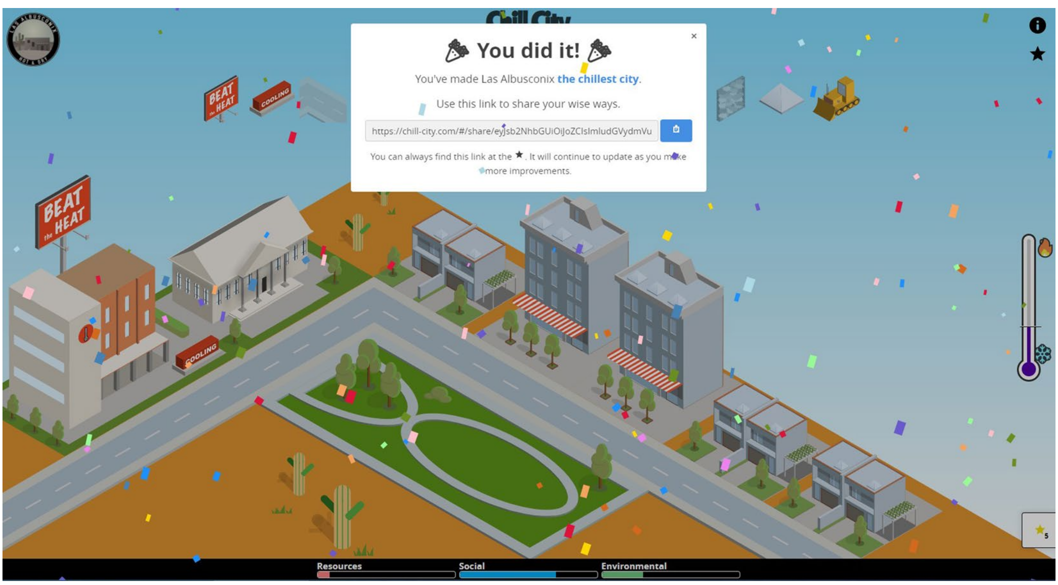

Figure 6. A player winning the game by achieving a minimum combination of social and environmental impacts within their resource limit.

enabling learning through the game. We modulated the impact of the various strategy scores, costs, beginning state (i.e., how many resources you begin with), and ending win state (i.e., how much "chill" impact is needed to win the game) to ensure that the gameplay was at an optimal level of pleasurable frustration based on user and internal feedback. In particular, we sought out player feedback regarding (1) frustration with gameplay that was decidedly unpleasurable, (2) the length of gameplay which would suggest flow, and (3) learning what gameplay conditions would suggest both flow and pleasurable frustration. This feedback was initially provided verbally through eight "beta testers," and later collected through open-ended survey questions. The share link functionality was added during this process to facilitate public sharing of the game and peer learning.

Testing the Chill City intervention

To test our intervention, we developed and administered a survey instrument before and after gameplay, collecting both qualitative and quantitative data on the players' reception of the game, learning outcomes related to extreme heat, and attitudes toward heat planning strategies (see Appendix B for the survey instrument). We collected user feedback both to improve the game design and to assess the potential role our educational game can have for environmental education, including exploring the game's potential impact on a player's stated openness to pursuing climate change adaptation strategies.

Before game play, participants rated, on a one to five scale, how often they think about extreme heat and how knowledgeable they are about extreme heat. These ratings were used to identify experts who might bias the results and to establish a baseline. Participants also rated, on a one to five scale, (a) their confidence in managing extreme heat in their personal life and their local community, (b) how high a priority extreme heat should be for their local community, and (c) how concerned they are about extreme heat. In a short answer format, participants were also asked to identify what kinds of strategies they thought should be taken in their personal life and in their community.

Participants then played *Chill City* via a link provided in the survey, and returned to additional post-game play survey questions where they were asked (1) the same questions again, (2) additional short answer format questions on their reasoning for selecting particular strategies in the game, and (3) feedback on gameplay. The game itself required about five to 30 minutes to play.

We distributed our survey to two target groups: first, a group of K-12 teachers participating in an environmental education professional development course, and then a snowball sample of non-expert members of the general public. The professional development course was offered at the University of Arizona for public school teachers in Tucson, had no direct connection to the authors, and yielded six participants with only two completing the full intervention. The teachers' results provided valuable feedback that helped us re-design and improve the game. However, because the teacher participation rate was low, we determined a need for a broader sample of participants and implemented the snowball sample to better understand the game's impacts.

To begin the snowball sample, each author distributed the survey to 25 acquaintances who were not involved in research generally or in any aspect of climate change-related work and who were loosely distributed across age and geography. These individuals were encouraged to forward the survey and game to their acquaintances with a small gift card raffle as an incentive, yielding an additional 75 participants. Of the 81 total initial participants from both samples, 30 completed the full sequence of pre-survey, gameplay, and post-survey. Twelve participants did not complete either the pre- or post-survey. Thirty-nine participants finished the pre-survey, started playing the game, and then stopped. While all the qualitative data were useful for improving the game, and while the 39 participants who started gameplay provided useful insight into a baseline condition for how the general public views extreme heat and expresses willingness to pursue heat mitigation strategies, only data from the 30 participants who completed both pre- and post-surveys were used to evaluate the outcomes of gameplay.

We used chi-squared tests to evaluate whether the changes in survey responses from before to after gameplay were statistically significant (p-value ≤ 0.05), especially regarding reporting an increased feeling of knowledge, confidence in taking action, and positive attitudes toward climate change adaptation. Given the high attrition rate, we were also curious if there were any statistically significant differences between the sample that finished playing *Chill City* and completed the post-survey versus those who had completed the pre-survey but then stopped before finishing gameplay or the post-survey. Therefore, we also performed chi-squared tests on the variation between these two participant samples. Finally, we analyzed the short answer survey data qualitatively using content analysis (e.g., Mayring, 2014), noted trends across responses by coding for particular heat planning strategies noted, described changes that aligned with survey question responses, and documented specific design issues regarding the gameplay.

Findings

Our findings are broken into four sections. First, we describe the outcomes of our quantitative analyses, which for the most part, failed to provide any insights due to a lack of statistically significant results. Second, we focus on qualitative findings, beginning with an analysis of participants' self-reported knowledge about extreme heat before and after gameplay. Third, we analyze the game's design and its ability to influence players' openness to heat planning strategies. And fourth, we consider an unexpected finding related to the game's design of private versus public strategies.

Quantitative analyses

We examined the quantitative survey data of those who completed the *Chill City* intervention and post-survey first—using chi-squared to test for changes in how many players felt more or less knowledgeable after gameplay, and in players' attitudes toward climate change mitigation. We found that neither of these changes were statistically significant. This may be a genuine reflection of the game not having an impact and/or it could be due to the relatively small sample size of those who completed both the game and the post-survey. We believe that it is likely the latter as qualitative results from the survey demonstrate positive impacts described by respondents, with design limitations related to legibility. We noticed at least one response where a participant described difficulty returning to the survey because they did not realize it was in a different window, suggesting that our survey instrument design may have also contributed, in part, to the low completion rate. In particular, our sample included older participants who were less familiar with computer use, suggesting that digital games for environmental learning are subject to the same limitations as other technologies subject to the digital divide. Those who are less familiar with computer use, or do not have easy access to the internet, may be a less appropriate target audience for the kind of learning that can come from a web-based game such as *Chill City*.

The only statistically significant differences were found in our secondary test of systematic differences between the participants who completed the game and post-survey (30) versus those that did not (39). In the pre-survey responses, we found that participants' self-reporting as more knowledgeable about extreme heat (X^2 (4, N = 69) = 9.49, p =.02) and more confident in their ability to manage extreme heat (X^2 (4, N = 69) = 9.49, p =.03) were both correlated with a lower likelihood of completing the post-survey after beginning *Chill City*. This might be either a reflection of more expertise leading to displeasure with the game's level of complexity or perhaps a broader self-selection by those who feel sufficiently knowledgeable, not being interested in learning more or having the patience to figure out how to play a game. Either way, this unexpected result suggests that additional design research is needed to learn how the game might better engage those who believe they are already knowledgeable about extreme heat and associated strategies.

Qualitative findings on self-reported learning

Despite the lack of statistical significance in changes in the question response ratings, the qualitative survey results from the open answer questions provided several useful insights. Most participants who completed both the pre- and post-survey described an increase in feeling knowledgeable about extreme heat, confidence in themselves, and/or confidence in their community to undertake heat planning strategies after playing the game. A few players described feeling extremely knowledgeable about the issue prior to using the game and reported feeling less knowledgeable after playing the game, perhaps indicating that they gained a better sense of how much more there was to learn about heat planning strategies through playing the game.

Players often responded that they were "unsure" of how to respond to extreme heat in their personal life prior to playing the game, and many indicated an interest in learning more about shading structures and cool roofs for their homes after playing. Similarly, some players were unsure of what could be done at the local level prior to playing the game. One respondent speculated that "less automobile traffic is a way to begin" but that they "need to research more." Another reported before playing the game that they were "not sure" about local strategies, asking, "What can local communities do? Seems like a national/international problem to address." The general understanding of how to solve climate change is accurately addressing the root causes of greenhouse gas emissions. But this is seen as out of the hands of individuals, leaving people unsure of how to respond. Smaller scale actions at the personal or community level, on the other hand, were not well understood. After playing the game, participants responded more uniformly about what heat planning strategies are available, including increasing green spaces, green infrastructure, trees, cool roofs, cool streets, and providing cooling centers.

In all, the self-reported learning that came out of gameplay suggests the presence of flow and pleasurable frustration, reflecting scholars' observations of these elements' connectedness with each other and, especially, with learning.

Game design and openness to heat planning

Player responses also suggest that the game adequately conveyed the notion of tradeoffs, with participants describing their decision-making process as trying to get the "most bang for the buck," as they sought "lower cost" strategies with a higher payoff. Players described that they "enjoyed balancing financial resources with changes" and that playing helped them "realize the relative resource-cost of various interventions." This exploration suggests the presence of flow resulting in increased awareness of heat mitigation strategies and, in turn, the possibility for increased openness to such planning policies and interventions. Even after implementing our multi-step process for game design to facilitate learning, however, a handful of survey responses noted confusion about some elements of the game including the "bulldozer" tool that could be used to remove a selected strategy, limiting the degree to which some players could adequately explore the various tradeoffs. These reports of confusion suggest that additional design iterations to improve gameplay are warranted to increase gameplay coherence.

Another element that emerged from survey responses was the "fun" nature of the game—suggesting we achieved a balance of both complexity and mystery in the game design. Players also reported that the game was "non-judgmental," allowing them to learn without the sense that the information was politicized. This, too, is a positive indication for the game's potential to facilitate grappling with the political complications of adopting needed climate-related policies. Extreme heat danger has caught many governments flat-footed in both policy responses and public communications. Innovative means to communicate possible policy interventions, build political support, and educate the public are needed but not readily available. Our game also demonstrates such innovations' potential as a means for two-way communication between policymakers and the public, with games posing an effective means for soliciting input and engagement: our players provided their preferred interventions through gameplay and the post-game survey, with many reporting an increased grasp of and strong support for installing cool streets from among the many strategies posed in the game.

Public versus private strategies

One unintended gameplay outcome we identified was that the private strategies (i.e., something a single building owner might implement, such as cool roofs) often appeared less expensive to a single user than public strategies (i.e., something a city might implement, such as cool streets), and with higher payoffs, so the game design may implicitly encourage players to prioritize private, small scale, and individual heat planning strategies despite the importance of well-coordinated public heat planning efforts.

While a relative cost is specified in *Chill City*, there is no distinction between costs borne by the public sector, the private sector, or an individual. This design flaw decreased gameplay legibility and is one that needs to be resolved in a future iteration of the game. Legibility on the relative cost could be increased by recalibrating the scores further, clarifying the qualitative impacts described, or modulating the number of private locations on the game board and requiring additional effort in applying these small-scale strategies across many more individual buildings. Additionally, different "player perspectives" could be incorporated so that the player could adopt different roles (e.g., a public official versus a building owner) and reason on their behalf as problem solvers. In particular, giving a player the role of "public official" might encourage greater engagement with strategies associated with the public sector, such as cool streets or public parks.

Conclusions: Gaming pedagogy for environmental policy

Through a design-based research process, we set out to build an interactive game that would help educate players about planning for extreme heat at a local level. Our game design and development aimed to address two commonly identified problems in environmental communication and education. First, the game was focused on action-oriented solutions and policies rather than framed solely around the vast and often negatively conveyed underlying problem of climate change (Bloodhart et al., 2019; Brosch, 2021). Second, the game focused on local and tangible urban planning interventions to mitigate heat rather than on the often-abstract interventions required for reducing greenhouse gas emissions.

A problem-oriented framing focusing on a global scale can result in frustrated learners who shut down (Reckien & Eisenack, 2013; Wu & Lee, 2015), while our players instead demonstrated positive learning outcomes and a willingness to engage with local strategies. Most games that exist within the literature tend to focus on the global dynamics of greenhouse gas emissions (e.g., Carfí et al., 2021; Cramton & Stoft, 2012; Lenton, 2014; Tollefson, 2008; Wood, 2011), leaving open the opportunity to create effective learning games that facilitate players grappling with the local climate change adaptations that will inevitably be required in the coming years. Our qualitative findings supported that games like *Chill City* have the potential to increase adult learners' feelings of knowledge about climate-related issues and their confidence in tackling those issues.

A key limitation of our study, however, was that our quantitative results were not found to be significant, likely due sampling issues and a small N. Related to this is the number of participants who skewed toward familiarity with the arid Southwestern climate of Tucson, and who likely had a greater degree of familiarity with extreme heat than individuals elsewhere. Our mixed results suggest that more design research is likely needed to develop and test further refinements to game design; to examine how potential impacts may vary across different climate issues, geographies, game designs, and populations; and to explore whether quantitative impacts might be detected after implementing design changes and/or utilizing larger sample sizes for greater statistical power.

Another limitation of our study and an important qualification for the positive environmental learning and policy outcomes of educational games is that their impacts are highly contingent on the game design (Sheppard, 2012). Our limited resources, especially in comparison to companies and organizations that develop games professionally, meant that we were only able to push the iterative game design process so far. Nevertheless, we saw promise in our study and imagine that there could be a much greater impact with commensurate resources for game design and development.

It is important to rely on insights from game studies to maximize a positive gameplay experience through flow (Csikszentmihalyi, 1990; Kiili, 2005) and pleasurable frustration (Annetta, 2010; Gee, 2004). Reflecting on the game design through Kaplan and Kaplan (1983) preferences of coherence, complexity, legiblity, and mystery also provided an important framing for the balance of gameplay elements. These elements proved critical to ensure that players achieved the desired learning outcomes regarding extreme heat planning interventions and their tradeoffs. We recommend future similar studies also use a rigorous and iterative design process to ensure that gameplay yields desired learning outcomes. As our study demonstrated, despite the mostly positive self-reported results, we may have unintentionally skewed players' learning toward favoring private and building-scale strategies. Finally, our results also suggest that environmental games may not be enjoyed or perceived as worth completing by everyone, especially those who already feel that they are knowledgeable about an issue, and this population may benefit more from other educational interventions. Nevertheless, games hold potential as a form of environmental education that can serve the general public, and especially as a form of gamified public participation in policy-making decisions. Players noted how their experience gave them hope for "getting people talking and acting" and how it helped them "think creatively about solutions"—an important first step toward resolving the increasing climate crisis.

Note

1. The *Chill City* game is freely available to be played online at http://chill-city.com.

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