Gamification for Climate Change Engagement: A User-Centered Design Agenda

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ABSTRACT

Policymakers and environmental organizations are increasingly implementing gamification because of its ability to stimulate playful learning and transform human attitudes and behavior. Although it has become a prominent development for climate change engagement, the literature does not adequately address how the underlying motivational systems depend upon user-centered design mechanisms. If gamification is to realize its potential for climate change engagement, it is crucial for designers to apply solid user-centered design principles, as suboptimal designs may do more harm than good. Therefore, we conducted a systematic literature review on gamification for climate change engagement to investigate the application of user-centered design and find key links between design choices and outcomes in 64 articles. We develop the findings into a user-centered design agenda and framework for game-based climate change engagement. This agenda includes design aspects–team multidisciplinarity, context dependence, user involvement, iterative testing, and design choice explication–and outcome aspects–value to users, game mechanics for learning, game content for learning, affective engagement, social engagement, changing real-world behavior, and using game data for research. The agenda is intended to inform gamification academics and practitioners aiming to design effective games for climate change engagement and its recommendations may apply to other complex issues.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; • **Social and professional topics** → *User characteristics*; • **Applied computing** → **Education**.

KEYWORDS

gamification, serious games, game-based learning, sustainability, climate change engagement, user-centered design, human-centered design, design guidelines, design agenda, framework

Mindtrek '23, October 03–06, 2023, Tampere, Finland

ACM ISBN 979-8-4007-0874-9/23/10.
https://doi.org/10.1145/3616961.3616968

ACM Reference Format:
Daniel Fernández Galeote, Mikko Rajanen, Dorina Rajanen, Nikoletta-Zampeta Legaki, David J. Langley, and Juho Hamari. 2023. Gamification for Climate Change Engagement: A User-Centered Design Agenda. In *26th International Academic Mindtrek Conference (Mindtrek '23), October 03–06, 2023, Tampere, Finland*. ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3616961.3616968

1 INTRODUCTION

Climate change threatens the foundations of humanity's well-being [49, 62] as well as that of many forms of life on Earth [72]. Change is required at all levels, from global leaders to individual citizens, and increasing awareness of our current ecological crises offers an opportunity to reshape our values, actions and systems so that we do not only survive, but thrive [48, 72]. As part of the solution, public and private organizations are increasingly designing and using games for climate change engagement as a means to stimulate various audiences' imagination, hold their attention, and promote playful learning to bring about awareness and changes in attitudes and behavior in practice [18]. In gamifying public engagement with climate science, they are adopting an alternative to traditional instruction-based, top-down methods [38] suited to the complexity of climate change [22] and its engagement [75].

Beyond its use to motivate climate change engagement in multiple forms and contexts [18], gamification has been used as a vehicle for transforming human cognition and behavior in contexts such as health, education, consumption, and prosocial behavior [33]. Given their multiplicity of applications, gamification and other motivational system approaches especially depend upon user-centered design practice (UCD) [31], which is not only crucial for the sake of usability and to cater for the complexity of issues such as climate change engagement [75, 77, 78] but for the principles of sustainability and ethical practice.

However, the gamification literature does not adequately address how the underlying motivational systems depend upon UCD mechanisms. The field of gamified climate change engagement currently lacks focused empirical analysis and design guidelines, including aspects of the process, the resulting artifact, and how its usage can lead to intended outcomes [18]. This lacuna is striking as design thinking is regularly promoted as a user-centered and iterative problem-solving approach to sustainability-oriented innovations in general (e.g., [6]), but those insights are not being systematically

translated into the design of gamification relating to sustainability attitudes and behavior.

If gamification is to realize its potential for climate change engagement, it is crucial for game developers to apply solid principles of UCD, as suboptimal designs may do more harm than good. The danger here is that poorly designed games result in unintended consequences, whereby users or potential users experience this topic as being dull, irrelevant or impossible to address in any meaningful way [61, 69].

Therefore, we conducted a systematic review of literature on gamification for climate change engagement to investigate how UCD is implemented across a range of gamification studies. We aim to answer the following questions:

(1) What UCD-relevant factors [4, 12, 23, 25, 47] are applied in the design processes of game-based climate change engagement interventions?
(2) What relationships are reported between design decisions and climate change engagement results?

The analysis and the design agenda presented in this paper are intended to inform academics that study gamification, as well as practitioners designing games for climate change engagement. The findings are new, as this is the first systematic assessment of UCD as applied to climate change engagement games, and we highlight five key design process topics and seven key outcome topics that, together, provide a design agenda. This is a valuable contribution because of the need to effectuate change in the ways that individuals think about climate change, how they engage with the challenges and their role in the transition to a sustainable economy. Theoretically, the analysis presented offers a structured set of process steps and mechanisms for realizing outcomes that scholars can use to inform their research. Previous research published at human-computer interaction (HCI) conferences [7, 8, 14, 15, 32, 44, 45, 71] evinces the community's interest in multiple points of contact between climate change as a sustainability issue and gamification research and practice. This, coupled with the interest in gamification design expressed by the HCI community (e.g., [10, 70]), leads us to consider that this contribution may be relevant to scholars in the HCI field.

2 BACKGROUND

2.1 Climate change engagement

It is clear that climate change engagement is still insufficient for sustainably addressing the emerging problems at different levels of our society and environment [48, 51, 62, 73, 74]. While the problem of engaging everybody to act is multidimensional and complex [37, 50], the stakes are too high to have a disengaged citizenship [77] as many positive changes depend on society at large adopting them [35]. But at the individual level, lack of information or even concern is not always at the root of lacking engagement. Rather, climate change information interacts with multiple personal and contextual factors [75, 78] embedded in human systems, habits and routines. Thus, climate change engagement has cognitive, affective, and behavioral components, all of which can interact with each other in complex and nonlinear ways [75]. While some researchers have examined various psychological and societal barriers that obstruct action [20, 21, 34], others have focused on psycho-social aspects shaping how we experience climate change, including "unconscious (or nonconscious) defense mechanisms, cognitive dissonance, anxiety, guilt, shame" [36, p. 28].

In response to the difficulties of engaging the public with climate change, message frames that consider specific audiences' concerns and interests are recommended rather than providing the same message for everyone [2], as well as those exploring not only the cognitive dimension of climate change but also positive emotions associated with climate action [5, 65]. Others have proposed, in addition, that persuasion should encourage forms of deep engagement such as perspective-taking in a way that connects the message with the audience's own values, mental model restructuring via personal risks, morality and systems thinking, and leveraging social norms [22].

Additional proposals include a shift towards dialogic processes [77, 78], other constructivist interventions [40], and an integrative model of engagement stages and media roles, including the use of interactivity, dynamic visualization, social interaction, personal and community-relevant information, and performing arts, visual arts and music [57]. Some authors suggest creating new radical listening-enabling methods that acknowledge some of the subconscious features of climate change engagement, such as anxiety, ambivalence, and aspiration [36]. These perspectives have created hope for the effectiveness of methods that involve people actively, such as games and gamification, in encouraging various collectives to engage with climate change, especially if the design process focuses on the user.

2.2 Gamification for sustainability and climate change engagement

Gamification can be defined as the transformation of systems and structures to afford experiences similar to those encountered in games with the intention to bring cognitive or behavioral changes [27]. According to this definition, the use of games, including serious gaming and game-based learning, are a form of gamification when they are used in climate change engagement interventions, as they transform contexts and activities that are commonly non-playful to afford a playful experience [27]. Thus, gamified applications need not only to be technically proficient, but they also need to affect users. At the same time, just implementing game-based mechanisms does not automatically lead to significant results; thus, to be effective, gamification design should aim to bring about gameful experiences, that is, engaging experiences [28, 30]. To ensure this, careful and iterative design is needed together with real users.

Gamification is being employed across a variety of dimensions of sustainability [33], including climate change engagement, where it has experienced growth during the last decade and has successfully engaged diverse audiences cognitively, affectively, and behaviorally (for reviews, see [9, 17, 18, 26, 58]). The advantages of gamification include, first, allowing players to explore problems and solutions actively [40], adapting to their performance [56], including events and entities with emotional significance to players [29], and motivating cognitive and behavioral change [27] through both intrinsic and extrinsic mechanisms [56]. These aspects acquire special relevance in complex, abstract and distant topics such as climate change, which can be made understandable, relatable, and close. However,

and beyond general aspects of gamification, the evidence on what design choices are effective for climate change engagement is not well understood. For this, the existing game-based studies are in need of synthesis and critical evaluation.

2.3 Gamification and user-centered design

Given the complex nature of gamification, which combines the needs to function, to engage, and to support changes, it is not surprising that these artifacts have a large possibility of failing [43]. This requires, in the first place, a clear definition of objectives, an identification and understanding of the context of use, and an intimate knowledge of who the users are [43]. These requirements are also in line with the principles of UCD [3, 39, 68]. Adapting gamification to multiple contexts rather than relying on one-size-fits-all solutions has been identified as an important design need to ensure effectiveness [66]. Factors such as the technology used, the task and its context, individual motivations, and emergent interactions between user and system should be understood and monitored for effective gamification [67].

It is not surprising, then, that most existing gamification design frameworks are based on user/player/human-centered design principles [42], as are professional game development processes [60]. This UCD attitude manifests prominently as user involvement during the development process. The need for user involvement and agency in systems development was identified already in the 1980s, when three levels of user involvement in the design process were identified: design for users, design with users and design by users. This has also been closely linked to the Scandinavian tradition of information systems design and development [4, 12, 25].

While a "design for users" paradigm, where users act as passive recipients of the design solution, can lead to designs that do not achieve their intended purposes for gamification, such as engagement and climate change awareness [59], design paradigms that involve the user directly offer clear advantages [59]. Such is the case of the "design with users" paradigm, where users are sources of information and testers of design solutions, encapsulated into the international standard for UCD process [31]. It is also the case of "design by users," closely linked with the co-creation paradigm, participatory design and maker movement, where users themselves are in charge of the design [4].

Whatever the level of user involvement chosen, in UCD the users are active participants [25] who are genuinely heard and whose experiences, views and opinions are respected. In other words, they are empowered. In addition, the users involved should be representative of the target user population and have the same level of previous knowledge, skills and other relevant characteristics [25]. However, in some cases the designers do not use the real users during the design process, rather recruiting friends, colleagues or anyone conveniently available to test their design and collect data, whether they are representative users or not.

In addition to user participation, other principles have been highlighted in the literature. One aspect that is explicitly brought up in the UCD international standards is the multidisciplinary design team [31, 39]). A design team that consists solely of technology/coding-oriented developers is not going to get the most out of the user involvement during the design process. Therefore, the design team should be multidisciplinary, consisting of usability experts, domain experts, gamification experts, etc. Another key element is understanding and specifying the context of use [31]. This is to specify the physical, social, organizational, and technological conditions and characteristics during the future use of the design.

While not explicitly stated in the standards of UCD, the level of formality and care that is put into planning, conducting and analyzing the user tests is crucial. Formal user/usability testing in both laboratory and in the field has a very long history that has stood the test of time and technological developments (see section 15.2 in [68]). In informal testing, users are not typically given tasks to perform or there is no observation or note-taking, which makes results more subjective and not as reliable. Therefore, we argue that in order to provide the most reliable results from user tests, these tests should be carefully planned, formally executed and thoroughly analyzed. In addition, teams should follow an iterative design-evaluation cycle [25]. Having just one round of testing in the design-evaluation cycle, the changes made to the design based on the findings of the user tests or expert evaluation methods are not subjected to testing and therefore these changes can cause issues as well as fix them. By repeatedly redesigning and retesting the design solution, the end result is a design that is much more polished and far better.

An additional layer must be considered when designing for climate change engagement, as players interact in very complex ways with the phenomenon of climate change even through games [16]. Multiple guidelines have been offered to aid the game designer interested in the field, from techniques for climate engagement through video games [52], to frameworks for game-based sustainability [11, 13] and pro-environmental design tactics [76]. These have been created through theoretical derivation, game analysis, and expert consultation and discussion. Thus, we lack a set of design recommendations that focus on gamified climate change engagement, both digital and analog; extend to both the design process and the product; and do so from an examination of empirical gamified interventions in the area. The multiple gaps identified in existing interventions both in researching the issue and in the games' design [18] warrant the contribution of an empirically derived agenda to facilitate the challenge of engaging players with the topic on all levels, namely cognitive, affective, and behavioral.

3 METHODS

This study gathers data from empirical scientific literature on gamified climate change engagement interventions, digital and analog, following a systematic process [54]. Our purpose is to understand current practices and to issue specific, evidence-based recommendations for future game and gamification design and implementation that engage players with climate change. Our adoption of UCD theory as basis for our analysis and recommendations recognizes that user- and context-related factors decisively influence interventions and their outcomes [53].

The search for literature took place in February 2020 and included automated database search (Scopus, Web of Science, EBSCOhost GreenFILE, ProQuest Central, IEEE Xplore, and Google Scholar) combined with a forward snowball sampling of the studies that complied with the exposed criteria. The search strings used, based

on our previous knowledge and various pilot searches, included the following terms:

('climate change' OR 'global warming' OR pro-environmental OR (environment OR ecolog* AND sustainab*) OR greenhouse OR low-carbon OR 'energy efficien*' OR 'energy consum*' OR 'circular economy' OR 'recycl*' OR 'extreme weather' OR 'extreme event' OR 'environmental acti*') AND (gamif* OR 'game-based' OR 'board game' OR 'card game' OR 'video game' OR videogame OR 'digital game' OR 'mobile game' OR 'online game' OR 'computer game' OR 'serious game' OR 'educational game' OR 'role-playing game') AND NOT 'game theor*' AND NOT computing.*

The search yielded 1453 results. After aggregating the search results and removing duplicates, the first and second author conducted the screening process in two stages: first, a review of titles and abstracts, with skimming of the full text if needed, and a full read of the retained papers and review against the inclusion criteria. The inclusion criteria included content applicability (the source describes a game-based intervention that aims to engage participants with climate change or otherwise reports climate change engagement-relevant results, is explicitly connected to anthropogenic climate change, and reports empirical results), and format (the language is English and the publication is a peer-reviewed journal, conference, or book).

The papers were independently screened by the two first authors, who met to compare results after the first and second screening stages. Disagreements were discussed until an agreement was reached. An initial set of 51 primary studies was identified, with 13 additional ones selected after a forward snowballing process for a total of 64 articles. The detailed literature selection process and the articles' identifiers (i.e., A01-A64) can be found in the supplemental files.

For the data extraction phase, the two researchers agreed upon the variables of interest and independently extracted the following data through careful reading of each article:

(1) Design process aspects as described in section 2.3, including UCD principles and other analytical lenses from [4, 12, 23, 25, 47]. These include multidisciplinarity of the design team, the report of design principles identified by the authors (including game design frameworks, best practices and explicit expertise but also substantiated interaction, usability, or playability considerations), the design adaptation between solution and context of use, the user orientation (design for, with, or by users), user empowerment, testing conditions (intended users or convenient testers, group size, in context or out of context), type of testing (formal or informal), iterativity, and the demonstration, or not, of a general UCD orientation as per the above indicators.
(2) Reported links between conscious design decisions, whether UCD-driven or not, and climate change engagement outcomes.

After a pilot data extraction of 5 papers, after which the two researchers met to adjust and clarify the process, data extraction occurred independently and in batches of approximately 10 papers at a time. At the end of each batch, the researchers met to consolidate the findings and ensure that no problems had arisen. At the end of the process, the independent observations were joined.

	UCD-compatible	Unknown or non-UCD
Design team	15	49
Design principles	29	35
Context adaptation	40	24
User involvement	18	46
User empowerment	15	49
Intended users	30	34
Formal tests	13	51
Iterativity	16	48
Overall UCD compliance	26	38

Figure 1: Amount of papers describing UCD-compatible versus doubtful or non-UCD practices.

4 RESULTS

Our analysis of the 64 papers resulted in two sets of observations, each answering one of our two research questions. First, we outline the studies' adherence to UCD processes (for a summary, see Figure 1). Second, we describe the ways in which designs have been reported to result, or not, in engagement. When considering the design process, we take the paper as the basic unit of analysis rather than the game. The reason is that a game can be studied in several papers, having changed in-between (i.e., the papers may reflect different stages of development). In cases where a design document or previous paper was referenced to explain the design process, the external source was reviewed to minimize uncertainty around it. In a few cases (i.e., A03, A34-A38), the external references provided new information that was considered in the following analysis. In the following, we avoid citing long strings of papers from our sample, but the reader can use the supplemental files to find the data described in subsection 4.1.

4.1 Adherence to the UCD process

4.1.1 Multidisciplinary design team. 15 papers (23%) reported having a multidisciplinary design team. 39 papers (61%) did not specify either having or not having a multidisciplinary design team. 10 papers (16%) allowed to infer that the design team was not multidisciplinary, although one of them (A27) declared reflecting an interdisciplinary approach.

4.1.2 Conscious use of design principles or best practices. Next, we identified the conscious use of design principles or best design practices during the design of the climate change gamification design. In total, 29 papers (45%) explicitly referred to some form of design principle or best design practice during the design process which

we identified as relevant. Some examples include accessibility considerations (e.g., A21), best practices in the field identified through a literature review (A56), co-creation (e.g., A27, A28), design-based research methods (A26), user-centered techniques in the Scandinavian tradition (A08, A11), participatory design (e.g., A44), transparency and facilitation (A48), or an understanding of the context of use (e.g., A09, A20). Two papers (A10, A29) implied that some kind of design principle or practice was used, but no further details were given to identify these. Twenty-six papers (41%) did not provide enough information to identify if design principles or practices were used or not. Seven papers (11%) described a design process that did not seem to use any principles or practices.

4.1.3 Context adapted for or taken into account in the gamified solution. Two papers (A09, A20) identified taking into account the context of use, as well as adapting the context for the gamification design. Thirty-eight papers (59%) involved a degree of context-sensitive gamification design, where for example the geographical location, the class curriculum, or some other contextual feature was taken into account when designing the gamification elements. Twenty-four papers did not specify if the context was adapted for or taken into account in the gamification design.

4.1.4 Design for users, with users, or by users. Based on how the design process was reported, 35 papers (55%) used the "design for users" paradigm, where the users were not active participants in climate change gamification design. Interestingly, some papers in this category claimed to use a UCD process, but in fact little or no user involvement was reported during the design phase and users were involved mostly during the evaluation phase and no redesign was done.

Eighteen papers (28%) showed active user participation during the design process, user empowerment and genuine participation. Furthermore, some papers presenting design for users (A11, A15, A18, A26, A53, A64) had the intervention as part of a process with users, despite the design not having clearly been tested with users before.

We did not identify papers belonging to the "design by users" paradigm, which was surprising due to the amount of user generated content, levels and mods in gaming, but partly it was not surprising as in these cases the design was done or evaluated for research purposes, and therefore none of the papers had their focus on co-creation or user generated content as such. Two papers (A14, A46) presented playful methods (game creation jams and workshops) where participants created their own games, but they were categorized as design for users since the gameful activities considered in our review were the events themselves, not the resulting games.

Eleven papers (17%) did not report their design process clearly enough to identify the level of user participation or did not report the design process at all due to them having adapted a pre-existing game.

4.1.5 User empowerment. Fifteen papers (23%) explicitly outlined genuine user empowerment during their design processes, highlighting how user involvement was crucial in the design outcome. 8 papers (12.5%) implied some degree of user empowerment, but did not provide enough details to assess the level of this empowerment. In token UCD process or in token user involvement, the users may be nominally involved with the design process, but their voices are not heard and they do not have any agency or say in the outcome of the design. Twenty-eight papers (44%) did not provide enough details to judge if the user empowerment was facilitated during the design process or not. Thirteen papers (20%) explicitly identified as having no or only token level of user empowerment, where users did not have agency and could not influence the design outcome.

4.1.6 Involvement of intended users. Thirty papers (47%) had the intended users of the gamification design taking part in the design and evaluation process. The rest of the papers either did not have any explicit user involvement during the design, involved only convenience samples, or involved participants from the real game's audience but the goal of the study was not to improve the design.

4.1.7 Formality of testing. Ten papers (16%) used formal testing methods and processes, while 3 papers (A10, A20, A29) reported having used both formal and informal testing. Thirty-eight papers (59%) did not provide enough details to assess the level of formality in their testing. Three papers (A18, A44, A63) mentioned explicitly some form of informal or ad-hoc testing. Ten papers (16%) did not report doing any kind of testing.

4.1.8 Iterativity. Sixteen papers (25%) explicitly identified or implied that more than one round of design and testing had occurred. Thirteen papers (20%) either imply some iterativity, without specifying if it had been one or more iterations, or directly mentioned one round. Twenty-five papers (39%) did not provide details about the level of iterativity in their design. Ten papers (16%) explicitly identified no iterativity in their climate change gamification design process.

4.1.9 Overall level of UCD used in the paper. Finally, the earlier principles and criteria are consolidated into an indicator or overall level of user-centeredness of the gamification design process. Thus, we searched for any signs of iterativity, incrementality, participation, a mindset where the user is considered as the most important aspect, or utilizing any forms of iterative design, user testing or user empowerment, either explicitly or implicitly. We considered the design user-centered if it included at least one iteration of design and evaluation with representative users, or if there was a sign of user participation in design or testing. Twenty-six papers (41%) showed UCD and user-centered attitude in their reported design process. However, 23 papers (36%) did not explicitly say how the design process was done and it was left unclear if UCD was done or not. Conversely, in 15 papers (23%) it was clear that the climate change gamification design process outlined in the paper was not user-centered and the users were merely passive recipients of the design solution, without significant involvement or agency.

4.2 User-informed game design practices

One central question in gamification is "what works?" While this question hides much complexity (what works for what, for whom, in what context, and in relation to what else, for example), we examined the 64 papers for information that would establish relationships between intervention features and outcomes. Therefore, these principles have been established based on user experiences

and outcomes as described in the interventions. Next, we present the lessons learned from all 64 studies. These are organized in three phases relevant for UCD: defining the context, designing the game for specific audiences, and evaluating and testing [31].

4.2.1 Context-informed gamification design. An important aspect of UCD is the integration of the artifact with its context of use, that is, who will use it, in what conditions, and for what. From the papers analyzed, it is clear that understanding the context can lead to **learning-supporting** designs, to player **motivation and enjoyment**, and to forms of **game production and reproduction** with extended value.

In terms of **learning**, gamification has been *integrated with instruction* to form a scaffold (A19), complement flipped learning (A33), consolidate knowledge (A20), and increase interest in the subject topic (A57). *Understanding student preferences* is essential for this, having noted that they prefer direct involvement and comparison than observation (A52) or conventional activities like quizzing (A12). Similarly, some of the studies reviewed *consider classroom limitations* such as crucial players missing sessions, which can be mitigated by dividing the game into multiple ones and having similar characters (A22), and the need to provide diverse roles and guidance so that dominant players do not impose themselves over others (A22).

Besides understanding the context of formal instruction, games should also be *adapted for use by experts and stakeholders*, who enjoy specialized discussion and simulating the future (A27, A28) but need a reason why playing would be relevant to them (A27, A28) and even criticize the use of a game for a serious purpose (A27, A28, A40). Games can clarify concepts hard to understand unless tested (A34, A35, A36, A37, A38) and extend previous knowledge through experimentation (A50). Games can be used in isolation to simplify complex topics, but they may be complemented with other activities too (A40). More specifically, *expert needs and preferences must be understood*, since they may mistrust simulations that cannot be verified (A51), notice inaccuracies (A27, A28), and expect systems to be coherent internally and with their experience, based on sources (A31), and transparent (A27, A28). Incorporating boundary objects that adapt scientific knowledge can enhance the credibility, legitimacy and salience of the game and its results (A27, A28).

Understanding pre-existing views in the general public is also important, since non-expert players will learn differently depending on their degree of acceptance of a simulation game's model (A61) and their recent experiences (A25). *Considering language* as a possible barrier is also important, especially when translating precise concepts across languages is difficult (A56).

Games not only to support learning, but also increase **motivation and enjoyment** (A54). Relevant variables for engagement include *location* (A27, A28), including region-specific characteristics (A18)–recognizing people and places can promote engagement and motivation to learn (A01, A53) and experts are motivated by realistic and plausible scenarios, even if not necessarily real (A51). Players from diverse geographical contexts may benefit from skilled and well-connected storytellers (A34-A38). *Gender* can affect both game interaction and climate change decision-making (A09, A34-A38), as do *age and literacy* with games (A08, A31, A32, A51, A53, A55), which affect preferences for or criticism of certain features. On occasion, even *resource limitations* can have unexpected positive results, for example when playing single-player games in pairs makes the experience more positive (A39).

Integrating games with their context can also yield benefits for their **valuable production and reproduction**, since games can be *shareable by design* beyond a single course or even institution (A41), across audiences and contexts (A04), and modified (A49). *Relying on external agents* for dissemination can help break barriers between research and the field (A51). Finally, *spaces for game development* have been created but enough time for innovation and proactive expert advice should be provided (A14).

4.2.2 Goal-informed gamification design. Another important aspect of UCD is to specify the goals that must be attained for an artifact to be successful. In this case, the broadest understanding of this goal is climate change engagement, including learning, an emotional connection, behavioral change, and engagement with the game, others, and the world.

The reviewed literature pointed out various aspects in which games were generally helpful for **cognitive engagement**, including as *an interactive entry point to complexity* (A03, A04, A13, A30, A40, A43, A53) which can incorporate scaffolding strategies (A62) and be more effective than traditional teaching (A20). Gamification can be *a channel to everyday concerns* by increasing personal relevance of knowledge (A26) and promote learning about daily actions (A32), decision-making processes (A07) and the future (A24). It can also be *a place for reflection* (A01, A10, A22, A29, A40, A49, A50) and *explore and model the future* to test practices and policies (A34-A38) and their consequences (A59, A60). *Social aspects* (A05, A60), including communication across sectors (A03), can lead to players learning from each other (A04, A26, A41, A48). Formally, games can be understood as *a medium* in which digital elements favor quickness (A11) and physical elements such as dice can concretize abstract processes and events (A40) and promote discussion and social learning (A11); *a frame for content*, either complex (A04) or simple (A10, A29), and a frame for social interaction (A50); *a visual display* reinforcing previous knowledge (A13), concretizing uncertainty (A60), and giving access to players' perspectives (A60); and *a creative endeavor* through which developers can exercise systems thinking (A46).

Beyond learning, a few features have been reported to promote **affective engagement**. *General knowledge and achievable actions* can give players a sense of meaningful accomplishment and reduce fatalism and overwhelm (A26), while adopting efficacious roles can increase hope and lead to affective learning (A48) and instructors can help promote hope in local action (A22). More broadly, gamification allows positive feelings of responsibility and competence (A33, A39). *Simulated events* allow experiencing discontinuity and surprise (A58), *freedom* affords optimism even if players do not behave pro-environmentally in games (A10, A29).

In terms of **engagement with games** themselves, studies have found that this can occur irrespective of the players' intrinsic motivation towards the environment (A16) and are used in educational settings to promote student involvement (A20), where satisfaction may be driven by challenges and educational content (A63). Apart from the recommendations for particular audiences outlined in

section 4.2.1., various elements have been reported to aid game engagement, including *quick feedback* (A27, A28, A53), *game characters* (A39, A57), *facilitators* (A40), and *physical elements* such as noise-making dice (A40). Conversely, *problematic elements* include interaction limitations, opacity and difficulty of use in single-player digital games (A07), as well as slowness and lack of control over the game's rules and boundaries (A13).

Apart from engagement with the game itself, some features affect **social engagement**. Games can promote communication, peer support, team-building, and improve the learning environment (A20). Game mechanics can effectively develop dialogue (A21). Specifically, *participatory methods* favor comfort and openness (A04), *complementarity and moderation* facilitate dialog (A31), *face-to-face debate* between diverse stakeholders combining urgency and optimism and involving multidisciplinary solutions nurtures positivity (A41), and *goal-related mechanics* (A34-A38) and role skills (A34-A38, A49) can increase cooperation. Beyond the confines of the game, *multiplayer role-plays* can promote community decision-making after the game (A49), especially if they are designed with this metagame, or discussions around and out of the game, in mind (A21).

Games can also present features that affect **individual behavioral engagement** in various ways. First, *after playing* (A06, A11), through game decisions influencing future course of action (A50) or shifting attitudes, which can result in behavior change (A06). Second, *as part of the gameplay* (A44, A26, A64), via activity tracking, eco-visualization and climate footprint (A15), as long as users see an explicit value in these (A45). In education, feedback and rewards reinforce motivation and commitment of the students to studying in advance (A57), but peer features can motivate players to teach others about climate change (A26). In addition, *making games* in itself can be a modeling practice (A46).

Games can not only be useful for players to engage with climate change, but they can also pursue goals pertaining to **research and data-driven game design**, for example by showing how players view science and to confront models with observations (A40). *The game design itself* can reflect the research aim (A50) and research instruments built in the game (A35), especially in digital games where collecting large amounts of data is easier (A18). Games call allow players to *refine their answers*, which improves the quality of their provided solutions to climate change challenges (A27, A28). This is important if these are an output to be collected for scientific inquiry.

4.2.3 Evaluation-informed gamification design. **Evaluation and testing** are essential phases of the design process to ensure that the design fits the context, its intended users' needs, and the intervention's own goals (A21). For example, *prototypes* can be an inexpensive way of testing concepts, but their lower quality can impact learning outcomes and engagement (A19). *Insufficient graphics and bugs* in digital games have been found to make experiences less enjoyable for young students, thus prompting fixes as part of the design process (A63). *Involving stakeholders* can strengthen the game's legitimacy and promote discussion already before playing (A23). *People appreciate being actors* in a study rather than just passive recipients, at least in professional settings where their expertise is directly related to the topic (A23).

5 DISCUSSION

In this article, we examined the design aspects of using gamification for climate change engagement. First, we investigated key aspects of the design process. When looking at the most apparent aspect of the design process, the actors conducting it, we found that only 15 papers explicitly reported involving a multi-disciplinary team. Almost half of the articles involved and identified some form of design principle, from accessibility to participation, context understanding, or particular user-centered techniques. In particular, 40 papers showed context sensitivity, either adapting the solution to the context or adapting the context to the solution. A majority of the papers followed the design for users paradigm. Crucially, no studies seemed to involve design by users, even if two of them involved game creation rather than game use. A few studies did not report enough details to clearly grasp the users' involvement level, which points implicitly towards design for users but evinces the low priority given to extensive design process descriptions, whether it's an omission, a choice, or born out of external constraints (e.g., journal space limitations). Only 15 studies clearly empowered their users as part of the design process, while less than half involved intended users as testers. When it comes to formal testing, once again a minority of studies (13) engaged in them, with the rest either providing too few details to know or not conducting testing at all. Iterativity in testing was even less common, with only 16 studies clearly saying or implying that more than one round of testing had occurred. Of the individual UCD practices examined, only context adaptation was found in most of the papers, while the rest are clearly reported only in a minority of studies.

Considering the above factors, only 26 studies seemed to follow a UCD process, while most either did not share enough information to assess them or directly pointed towards processes where users were passively involved in the design process. Therefore, it is evident that even though professional game development processes and game development companies are largely user-centered [60], most of the papers in this study did not explicitly detail the design process as being user-centered.

This points to two possible issues–either the design process is not UCD-compatible, or the reporting is insufficient to know. In the first case, we argue that UCD is the best way of ensuring that the designed game will achieve its intended effect or purpose, be it engagement, raising awareness, behavioral change or other. Naturally, gamification design could be empowering in some way for the user even if the design was not done using UCD process or best practices, but we argue that in those cases the effect of the design was because of luck, intuition or tacit knowledge rather than good design, and as such UCD should be preferred when designing effective climate change gamification. To support gamified climate change engagement UCD processes, we offer a design agenda below. In the second case, unclear or insufficient reporting, we are mindful of space limitations. However, we argue that researchers should attempt to describe as many aspects of the design process as possible, since it is relevant to contextualize a study's outcomes and clear reporting fosters a culture in which the design process is both transparent and valued.

Our second set of results examined possible links between design choices and outcomes. Here, we observed multiple explicit

connections between measures taken to understand the context and engagement with the resulting game and climate change, especially learning. In this regard, we uncovered various individual and contextual aspects to consider, including language, occupation, interests, gender, and location. We also found a few recommendations for valuable game production (e.g., in game jams) and reproduction (i.e., reusing and repurposing). We also found design aspects linked to cognitive, affective, and behavioral engagement with climate change, including game types and formats but also specific mechanics and ways to deliver content. The sample detailed ways in which players can engage with games themselves, others, and the world outside of the game, as well as contribute to research and data-driven game design. A few articles also described ways in which evaluation and testing can contribute to improve the design process.

Next, we provide a design agenda based on our results, both in terms of the design processes followed and the relationship between design choices and the outcomes obtained. Figure 2 summarizes it as a framework.

5.1 Design agenda for user-centered game-based climate change engagement

Our design agenda starts with a series of recommendations for improving the design process of gamified climate change engagement according to UCD principles, as well as the scholarly communication of such processes. While it has been crafted from an analysis of literature in this area, it may be applicable to gamification design for complex topics and wicked problems, including other sustainability and environmental issues.

(1) **Team multidisciplinarity. Design teams should incorporate multidisciplinarity whenever possible and relevant.** Effective design benefits from knowledge of, at least, the method (game design, interaction design), the content (here, climate science, policy, and other fields), and user research (sociology, psychology, learning sciences, and HCI). Inside each of these areas, further complexity may appear; for example, games can be seen as an assemblage of mechanics, art (at least visual and audio), stories, and technology [64], each of which may require one or more separate professionals.

(2) **Context dependence. Designers should adapt their games to the context in which they are used, and/or seek ways to adapt the context to the game.** Given the diversity of personal and contextual factors that affect climate change engagement, it is important to understand the context where a game will be used and to ensure that the artifact matches it. Different audiences (students, experts, lay people) have different expectations of games, different ways to interact with them, different preferences in terms of mechanics, content, and aesthetics, and expect them to be used for different purposes. Designers should understand the game's goal and context of use, but also the users' characteristics such as occupation, age, gender, familiarity with games, local environment, language, need for accessibility, transparency and facilitation. If a game's aim is to engage all audiences, even those who are already engaged with climate change and sustainable behavior, its content should be shaped accordingly. Thus, interventions should be designed and applied by taking into account the profile of the audience or the user characteristics. Even if frictions can be productive and surprises

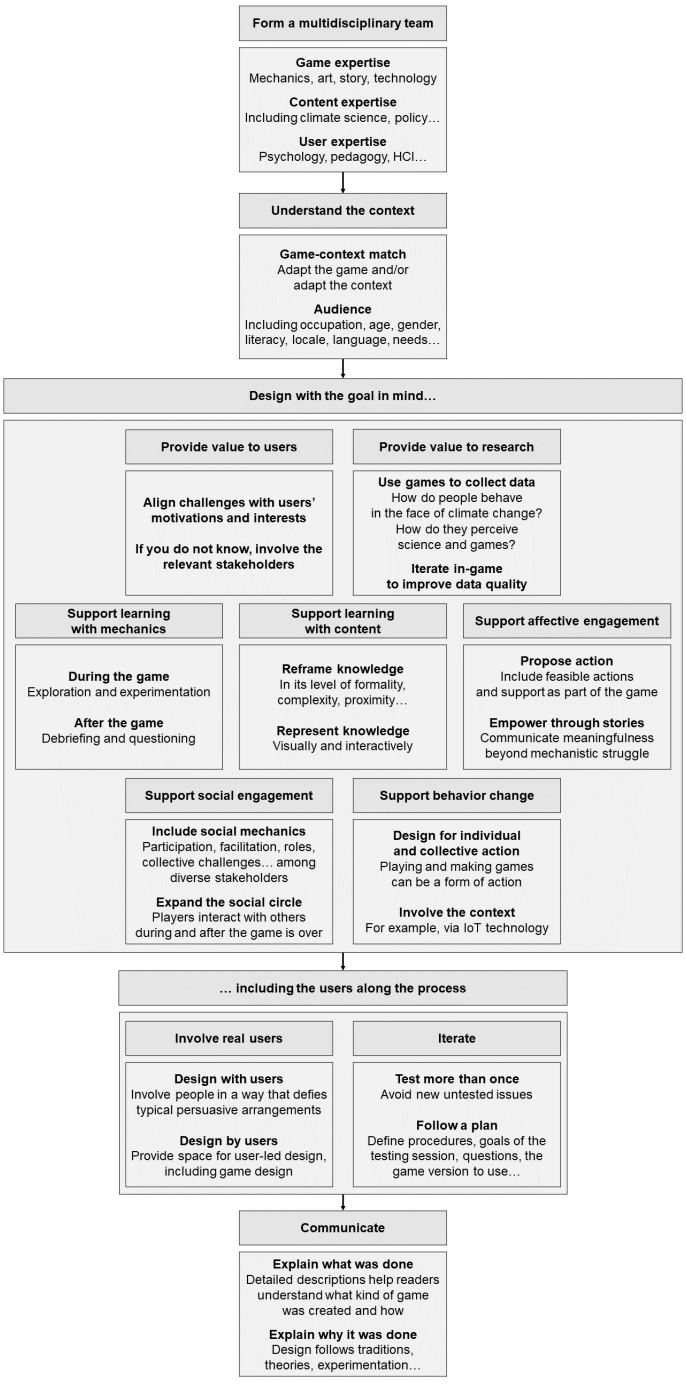

Figure 2: User-centered design for gamified climate change engagement framework.

welcome, clear communication should strive to minimize unintended issues. In addition, designers should consider the benefits and tradeoffs of context adaptation. Can a limitation, such as having few computers, become a strength of the game via social interaction? When can a game be reused or adapted, which would increase the sustainability of the study?

(3) **User involvement. Intended users should be involved more in the design process, especially in ways that keep them active and empowered, for example in design with users or by users.** Design with users was rare (18 papers), while no papers studied game design using the "design by users" paradigm. However, two studies (A14, A46) presented gameful interventions which, although designed for users, allowed different audiences to create games as a form of engagement with climate change. Given the potential of constructionist interventions, the engagement derived from feeling being an active participant of a study, and the unique knowledge that audiences have of their needs and contexts, placing more trust in users to create the solutions that they themselves will utilize represents an exciting, and neglected, space to explore. In addition, the local specificities of climate knowledge and the benefits of dialogic designs [1, 77] open a door to meaningful co-creation and participation defying the idea of games as persuasive media where the roles of the expert broadcaster and the lay audience are clearly defined.

(4) **Iterative testing. More user tests should be conducted, and the ones conducted should be described in more detail.** Iterativity is a key aspect of UCD, and more than one round should occur to avoid new untested issues. This was clear in only 16 papers. Constant game testing and evaluation ensure that games are technically as error-free as possible to avoid unsatisfactory experiences (A63). Furthermore, most papers did not show whether formal testing procedures had been conducted, so more explicit testing procedure descriptions are needed. Prototypes can be used, but this may limit player enjoyment–designers should understand when to use an unpolished prototype and when to spend the resources on something more elaborate. In the area of climate change, and considering the multiplicity of understandings, attitudes, values, and behaviors that players may have towards the issue, an intimate knowledge of how audiences respond to designs becomes crucial for effectiveness and leaves room for realizations on the part of the designers that even defy general conventions of gamification and game-based learning [16].

(5) **Design choice explication. Design descriptions in articles should be more clearly and generously explained.** We observed notable unclarity in the design process of many papers (23). Readers need to understand what was done to assess how to arrive at effective designs, and detailed explanations of what may have worked or failed, even if hypothetical. This is especially relevant in complex environmental issues such as climate change, since there may be limitless ways to frame and represent reality in a game [46]. Since readers have much to learn from others' design processes, authors should attempt to either be precise in their descriptions or point towards external resources such as game design documents whenever possible (e.g., A34, A35, A36, A37, A38). In addition, articles would benefit from clear explanations of the design tradition in which a process is conducted, and what novelties are being introduced. Otherwise, gamified climate change engagement risks living in a space where theories and attempts remain vague, repeated, and disconnected.

Next, we provide recommendations to improve climate change engagement and other typically sought outcomes through design, based on the literature.

(1) **Value to users. Designers should not only consider what scientific or engagement value games bring, but also what value games bring to the user.** Why would someone want to engage with a climate change game? Players will not engage with tasks if they do not perceive any value (A45). Overall, the goal of gamification has been identified as supporting "users' overall value creation" [30, p. 19]. Challenges should always be aligned with the users' motivations and interests. If these are unknown, their input must be part of the design process. In order to ensure that games deliver value to players, involving relevant stakeholders in evaluating and testing is important, especially given the multiple actors and contexts in which gamified climate change engagement takes place [18]. While some audiences may be genuinely interested in learning or behavior change towards a more sustainable way of life, others may be concerned about their cities or companies, or even doubt the importance of climate change, or the use of games, at first. Games made to support particular audiences, such as farmers, in particular regions (e.g., A02, A23, A27, A31, A50) speak of the importance of delimiting the player base and designing with them in mind.

(2) **Game mechanics to aid learning. A set of game mechanics seem to typically support climate change learning.** These are generally related to the simulational and inspirational capabilities of games. Games are great venues to encourage exploration, active learning, testing different possible futures, and to reflect, either during gameplay or after through debriefing, alone or together. Therefore, game designers should ensure that there are spaces for all or most of these actions, including during the game but also after, where space for questioning to support knowledge construction should also be provided. Given both the personal and the collective implications of climate change engagement [75], reflection and discussion are essential to its gamification. This is traditionally in the form of debriefing led by an instructor [19], but digital games can set up similar structures.

(3) **Game content to aid learning. Games can present content in new ways.** These new ways of relating to content, whether known or new, include a more informal setting, simplified complexity, and new framings that are not possible without the player adopting a role and interacting with systems and other actors. They also include presentations of

information that are not only verbal but also visual and interactive. Because climate change is a super-wicked problem [37] and therefore difficult to understand and relate to, it can be eye-opening to offer alternative and provocative representations of it, especially those that bring the phenomenon closer to the player and their reality.

(4) **Affective engagement. Game mechanics and stories can support affect.** People's relationship with climate change is underpinned by a wide range of emotions [55], and gamified engagement with climate change is not an exception [16]. The examined studies assert that proposing and enacting feasible actions and providing support can positively affect the emotional relationship between players and aspects of climate change. Importantly, one study found that direct pro-environmental action as a game goal may not be always necessary for this, but that experimentation in an open environment can lead to positive realizations (e.g., trust, hope) even if the player's actions are damaging to the simulated environment (A29). Beyond mechanics, more work can be done by connecting narrative theories with climate change engagement. For example, A12 links melodrama as a rhetorical device with mitigation education, although it does not report affective outcomes beyond game engagement. If all meaningfulness is conveyed through challenges, designers risk representing the direness of climate change through extreme difficulty, which can lead to a sense of fatalism (A61).

(5) **Social engagement. Game mechanics can engage players with games, but also with others.** It has been observed that quick feedback (responsiveness), ease of use and player control favor engagement with the game, but other mechanics have been put in place for social engagement: participation, facilitation, roles, collective challenges, and nurturing conversations around the game. Since it is important to involve diverse stakeholders in climate change-relevant decision-making, games can feature negotiation, collaboration, and a discussion of actions, norms, and values, which are central in real-world arenas. Importantly, there are ways to expand the social circle of a game beyond its traditional boundaries, so that not all stakeholders relevant to the conversation need to play the game directly. Including more elements for social interaction with non-players (as the game creation interventions A14 and A46 do, and A08 encourages via messages) would extend the social boundaries of interventions leading to opportunities for pervasive play [41], player-generated engagement, emergent connections, a sense of social relevance, and supporting relatedness [63].

(6) **Changing real-world behavior. Games can promote action.** Role-plays and simulations can motivate players' future actions individually (A06, A11) and collectively (A49). Since more effective climate action is needed, designs that support it as part of the gameplay rather than relying on transference from learning or attitude change are a good avenue for future work. Systems designed to promote lifestyle changes could make use of IoT devices to help players keep track of their performance in a way that is immediately integrated in their daily habits, and to adopt design approaches that allow players the freedom to choose their own paths [24]. Apart from this direct form of gamification, making games as a form of expression, persuasion, conversation and, in the end, action, is also an intriguing area of study.

(7) **Game data for research. Games can also help researchers collect data directly.** Game-based climate change engagement interventions can make use of the game itself to aid in the research process. Some papers in this review show that a combination of data logs and other collection methods can paint a nuanced picture of the game experience and reveal multiple signs of engagement. Games have been found capable of answering questions about how people behave in climate change situations or how they perceive science and games, which is particularly important given the impossibility to separate daily human activity and the climate. One method to improve player-made inputs, if those are to be examined later, is to iterate through them as part of the game, for example through several rounds of adjustment.

5.2 Limitations and implications

This analysis has depended on the original articles' degree of clarity. Therefore, it is possible that some studies did incorporate UCD practices without the analysts having been able to detect them. This is such an important issue that we have dedicated a point of our agenda to it. Another possible limitation of this study is the age of the sample, which was collected in 2020. However, its aim is the provision of design guidelines that go beyond a still image of the research landscape, and instead aim to propel the field forward. Still, as climate change and societies' relationships evolve with time, further work in the space of gamified climate change design will be needed.

The analysis and subsequent design agenda presented are a novel contribution to the area of climate change engagement. They bridge a gap between gamification and UCD practice, which should lie at its base but, as seen in this study, seems on occasion to be far from it. With the proposed agenda points, scholars and practitioners considering the design and application of gamified climate change engagement can have access to UCD recommendations that are informed by UCD at large but consider the unique standpoint of climate change and environmental sustainability practice. Thus, the proposed agenda opens up further practical avenues, but it also shows how UCD, gamification, and climate change engagement can be considered together in research. Given the multifaceted ways in which gamified climate change engagement has been explored in the HCI community [7, 8, 14, 15, 32, 44, 45, 71], we anticipate that the general guidelines proposed have the potential to be not just further adopted for a more informed practice but also adapted to a multiplicity of perspectives and practices.

ACKNOWLEDGMENTS

This research was supported by Academy of Finland Flagship Programme (337653—Forest-Human-Machine Interplay (UNITE)), the Nessling Foundation (project No. 202100217), and the European Union's Horizon 2020 Programme Marie Skłodowska-Curie Actions (840809).

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