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Climate change gamification: A literature review

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Abstract. Climate change is a global issue with impacts that span across ecological, social and economic systems. Climate change literacy and engagement are crucial in implementing successful adaptation and mitigation strategies to overcome the negative impacts of climate change. Gamification is one communication and educational approach that can be used to increase both literacy and engagement. This paper provides a state-of-the-art of climate change gamification research through a systematic literature review. The findings from reviewing 14 primary studies show that climate change gamification is a research area that deserves more attention from researchers as there is a limited number of studies addressing this important issue. More quantitative studies as well as longitudinal studies are sought, as they provide a higher strength of evidence of how gamification can enhance engagement. Only two controlled experiments were identified, while majority of studies relied on qualitative and cases study approaches. Gamification applications covered all functions of climate change engagement, namely delivering information, raising ethical awareness, and eliciting decision-making and behavioral changing through simulation. All studies, except two, showed successful application of gamification approach to climate change communication. Our literature review indicates also that more studies are necessary to advance the research area and we provide a research agenda with specific directions to follow.

Keywords: Climate change, Gamification, Systematic Literature Review

1 Introduction

Global climate change is the most urgent and far-reaching environmental issue that has affected the socio-ecological health [1,2]. The scientists have reached the global consensus that there is an urgent need to act to overcome the social and environmental impact of climate change [1,2]. The scientists estimate that we have 10-15 years in which to implement drastic changes in our lifestyles and policies to avoid dangerous levels of climate changes with severe impacts on nature and socioeconomic life [1,2]. The actions that people do today determine what kind of future the world and human-kind will face tomorrow.

However, it is not easy to educate and engage the public and policymakers towards such a complex issue as climate change [3]. Despite the increasing exposure to climate

change news, stories, experiences and recommendations, there are still discrepancies between public, policymakers, and scientific opinions on climate change adaptation and mitigation (see e.g., [4]). The climate change literacy plays a vital role in promoting good political decisions and changes in individual behavior and consumption patterns [5]. However, the traditional mass media communication of scientific climate change facts, information, and calls for behavioral changes has been shown to be ineffective to produce actual changes in individual behavior and living practices [3]. The main reason is that climate change is not perceived as a personally relevant issue, it is considered distant in both time and space, and therefore is also associated oftentimes with uncertainties and political and economic interests [3]. Therefore, new and more impactful communication means are needed to engage the public and the policy makers towards climate change issues through adaptation and mitigation strategies and actions (see e.g., [6]). Recent discourses on climate change communication highlight the need for a paradigm shift in communication, namely communication as interaction as well as a constitutive, meaning-making approaches to communication [7]. Both these approaches, communication as interaction and meaning-making communication involve some level of interaction and participation from the individuals, that is, a two-way communication that gives also a sense of empowerment and triggers agency [8]. One method that has the potential to engage individuals and various stakeholders towards climate change through interactive, participatory and meaning-making communication is gamification.

Gamification was originally defined as the use of game elements in non-gaming context to improve user experience and user engagement [9]. Games are appealing to researchers because of their ability to engage and motivate [10]. The idea of employing fun and game elements in computer-aided learning belonged to Malone in 1980s (see [11,12]). Games in general are powerful tools for creating positive emotions, enhancing cognition, and stimulating behaviour, and therefore they could potentially increase engagement with climate change. However, games are typically used in voluntary contexts and for entertainment. There are two main approaches to introduce games in practical contexts: serious games and gamification. Serious games (see e.g., [13]) are games that have a practical purpose, such as learning a language, developing a skill, understanding a complex concept or problem; they do not necessarily include a playful or fun experience, however, they embed rules and game dynamics that enable players to progress and attain specific goals, and also to learn about specific concepts and issues in the process of game play. On the other hand, gamification [9,14] represents an approach to inspire, motivate, change behaviour through game play or gameful experience. The same objective can be achieved through serious games and gamification, but using a different mechanism; e.g., in learning contexts, serious games influence the learner directly through the topic and story of the game, while gamification influences the learner indirectly by changing, for example, the habit, interest, and behaviour towards learning (see [13]). The gamification has been showed to improve motivation and engagement towards learning and performance, but just implementing some gamification mechanisms does not necessarily lead to significant results; thus, to be effective, the gamification design should aim to bring about gameful experiences [14,15]. In this paper, the term gamification includes all three approaches: games, serious games,

and gamification systems. A similar conceptualization of gamification was also employed by Koivisto and Hamari [10] in their review.

Gamification can bring climate change communication to a new level by harnessing the individuals' abilities and interests through well designed technological affordances. Climate change gamification applications can, for example, highlight the sense of urgency, accelerate the climate change awareness, while building a capacity and a sense of agency for changing the future through today's actions and behavioral change [16]. This approach has therefore the potential to address the psychological distance issue of climate change (see [3]).

Recently there has been an increase in studies that explore the potential of gamification in the climate change context; though these are not yet very numerous, they represent a promising and important step towards addressing the challenge of climate change. In this paper, we aim to analyze and synthesize the climate change gamification literature, with the purpose to provide a state-of-the-art overview of the climate change gamification literature to support further studies on climate change communication and engagement through gamification. The research questions guiding the study were: 1) *What research approaches are employed in studying gamification for climate change engagement?* and 2) *To what extent gamification is successful in engaging individuals with climate change?* To answer these questions, we characterize the factors employed in the gamification, the employed research methods, the strength of evidence, the publication forums and years. Thus, this review provides a very timely assessment of the current knowledge, development guidelines and best practices on the climate change gamification area. To this end, we conduct a systematic literature review (SLR) whose process is described in detail in section 2. Section 3 presents the results, and section 4 discusses the findings, implications and conclusions.

2 Procedure and methods

Analyzing the use, impact, and significance of gamification in climate change engagement, as well as identifying the ways gamification has been used in this context are especially timely and important. However, the research in this area is sparse, thus this paper aims at reviewing the existing research to identify empirical findings, as well as methodological and conceptual bases upon which to build further studies and propose a research agenda. In this study we aim to provide through a systematic literature review (SLR) an outline of the scientific publications that have studied the use of gamification in climate change engagement. The guidelines by Aveyard [17] are used as the main source and methodology for designing and conducting this systematic literature review (SLR). For specific information on the SLR pertaining to this study, we utilized also other sources that provided general guidelines for conducting SLR (i.e., [18,19]), and practical insights and examples about conducting SLR in gamification context (i.e., [20-22]).

After clarifying the aim of the review and formulating the research questions, we defined a search protocol and conducted the review accordingly. Preliminary searches helped to formulate the final search phrase and select the search database. Following

the guidelines of Hamari and Keronen [22], the search was undertaken in the Scopus database. The final search phrase was as follows.

("climate change" OR "global warming" OR "extreme weather" OR "extreme event") AND (gamification OR gameplay OR "educational game" OR "serious game" OR "computer game" OR "mobile game" OR "digital game" OR "online game") in the field Title-Abstract-Keywords.

To assess the suitability and relevance of a potential primary study, we created a list of inclusion and exclusion criteria (see Table 1). These criteria considered aspects relevant to the topics of this research (e.g., to include articles about climate change engagement and gamification in some form), the accessibility of the articles (e.g., language and availability), and the quality of the research (e.g., peer-reviewed articles that describe at enough level the research method and data).

Table 1. Inclusion and exclusion criteria for selection of primary studies

<ul style="list-style-type: none"> • Include if Written in English. • Include if Peer-reviewed journal or conference article. No limit regarding the publication year. • Include if Full paper available through Scopus, Google Scholar or library access. • Include if Research method is defined (empirical, qualitative, quantitative, survey, SLR, etc.). • Include if Paper addresses the gamification of climate change engagement.
<ul style="list-style-type: none"> • Exclude if Paper is not about engagement with climate change. • Exclude if Paper only mentions gamification (i.e., gamification is not the focus of the study, gamification is only brought up as a potential method). • Exclude if Paper is not about climate change, but other specific environmental issue.
<ul style="list-style-type: none"> • Include if Paper addresses any form of digital or physical gamification (computer games, online games, board games etc.). • Exclude if Paper does not study game, serious game, or gamification artifacts.
<ul style="list-style-type: none"> • Include if Quality requirements met (e.g., validity of inferences is clear). For empirical studies, data is identified (number of respondents, players, studies etc.). • Exclude if Empirical study does not make possible the identification of the data.

The search was conducted on 3rd of December 2018 and resulted in 86 search hits. Three of these were duplicates and removed, thus the dataset of retrieved primary studies contained 83 papers. These articles were first screened based on the title and abstract as to their fulfilment of inclusion and exclusion criteria. Twenty articles were retained as the result of the screening, while 63 articles were excluded.

The full text of selected articles was downloaded, read and evaluated as to their fulfilment of inclusion and exclusion criteria. Six papers were excluded for failing to meet the inclusion/exclusion and quality criteria. The list of primary studies selected for systematic review comprised 14 scientific articles. The selected papers were analyzed, relevant information was extracted, and the results synthesized in Table 2.

Table 2. Summary of selected primary studies ordered by year

Primary study	Research method	Theoretical framework	Type of gamification	Focus	Data	Strength of evidence	Results
Ouariachi et al., 2018 [23]	Mixed method case study	Influence of game on attitudes, self-efficacy and behavioral intentions	<i>2020 Energy</i> : questionnaire, simulation of sustainable decisions	Ethos	Game sessions and questionnaires from 58 students from Spain and 50 students from US	High (control group)	Unsuccessful, no statistically significant differences between experimental and control groups
Puttick and Tucker-Raymond, 2018 [24]	Qualitative, case study workshop	Sociocultural constructionist pedagogy	Game design as instructional tool for climate change	Pathos Logos	Interviews, concept mappings, user testing, final presentations, surveys, recorded video from 5 girls in middle school	Low (Qualitative case study with few participants)	Successful, emergent understanding of climate change as a systems problem
Flood et al., 2018 [25]	Systematic literature review	Social learning Cognitive, normative and relational learning	Serious learning component of games	N/A	43 selected publications	High (Systematic literature review)	Successful, adaptation games are an effective tool for engaging with diverse public and enable social learning
Parker et al., 2016 [26]	Qualitative, case study	Experiential learning	<i>Cauldron</i> : boardgame for addressing risks and loss	Pathos Logos	9 gameplay sessions with 14 to 44 participants from government, civil society and scientific stakeholders	High (Multiple case study)	Successful, participatory games can be used to engage multistakeholder groups in discussion around complex issues
Onencan et al., 2016 [27]	Qualitative, case study	Effective learning	<i>WeShareIt</i> : computer-assisted boardgame for climate-change induced disaster risk reduction	Ethos Logos	User test, pre-game questionnaire, in-game questionnaire, gameplay observation, post-game questionnaire, debriefing from 11 participants from public sector decisionmakers	Medium (Qualitative case study, small but in-depth set of data)	Successful, serious games can be used effectively in enhancing strategic foresight in climate-change related disaster risk reduction

Zou et al., 2015 [28]	Qualitative, case study	No theoretical framework identified	<i>Eco Eco</i> : mobile game for visual representation of the rising sea level effects	Pathos Ethos	Two user tests, 13 students who were 8 to 12 years old	Low (Qualitative case study, no theoretical framework, small set of data)	Successful, gamification provides the young players with better motivation to follow through some real-life green habits
Angel et al., 2015 [29]	Qualitative, case study	Experiential learning context	<i>Future Delta 2.0</i> : first-person realistic situatedness in local places	Pathos Ethos Logos	Co-design, user test, pre-survey, post-survey with 65 students from secondary school	Medium (Qualitative case study)	Successful, students were excited to play the game, preferring it to conventional book learning and retaining the information about climate change, its causes and possible solutions.
Avi Brooks et al., 2015 [30]	Qualitative, case study	Spatial and temporal dynamics	<i>Urgent Evoke</i> : earning points from completing missions in real life	Pathos Ethos	User test, class discussions with 160 college students	Medium (Qualitative case study)	Successful, alternative reality games have potential for building literacy of critical issues and understanding the long-term solutions to urgent problems
Nussbaum et al., 2015 [5]	Quantitative	Climate change literacy	<i>Losing the Lake</i> : online browser game	Pathos Ethos Logos	User test, pretest, posttest and delayed posttest surveys from 119 middle school students	High (Control group)	Successful, playing the game resulted in a significant increase in content knowledge while the control group showed no effect. Playing the game also showed some increase in the interest.
Van Den Homberg et al., 2015 [31]	Quantitative case study	Game-based Learning Evaluation Model (GEM)	<i>Ready!</i> : physical game	Pathos	User test, survey of 16 NGO staff members and 58 community people	Medium (Quantitative case study)	Successful, Community appreciated the game highly, great potential in embedding the game to disaster risk reduction training

Seebauer, 2014 [32]	Quantitative	Climate change knowledge	<i>Climate Quiz</i> : social media game	Pathos	Game data from 193 players	Medium (Quantitative study)	Partly successful, some tasks in the game did not provide enough entertainment value, quiz questions were much more fun, game design could be revised to minimize frustration from ambiguous questions, games can be used to collect scientific data
Schroth et al., 2014 [33]	Mixed methods	Climate change communication	<i>Future Delta</i> : first person simulator, climate change adaptation and mitigation	Pathos Ethos Logos	Quantitative preplay and post-play surveys for 18 students and qualitative interviews of 10 experts	Low (Quantitative and qualitative study)	Successful, 3D imagery and interactive environment can change perceptions and increase sense of responsibility and support for climate change adaptation and mitigation policies
Lee et al., 2013 [34]	Qualitative, case study	Climate change education, action-based learning	<i>Greenify</i> : real-world action game	Pathos Ethos	Design-based research with 26 participants as a convenience sample, in-game logs	Low (Qualitative, design-based case study)	Successful, playing the game was perceived as fun and engaging, resulting creation of user-generated content, motivated informed action, and creating positive peer-pressure
Dulic et al., 2011 [16]	Mixed methods, case study	Climate change education, behavioral change	<i>Future Delta</i> : first person simulator, climate change adaptation and mitigation	Pathos Ethos Logos	Pretest survey, user test, post-test survey with 26 students, interviews with 10 experts from different fields	Medium (Quantitative and qualitative study)	Successful, engaging with the game motivated the users to act to mitigate climate change and to support social changes for climate change mitigation and adaptation

3 Results

We analyzed the 14 primary studies systematically and coded them for issues relevant to this study. Two categories of issues are extracted: research methods issues, and topical issues related to climate change gamification. Table 2 presents the selected primary studies and the results of the analysis. Together with the characteristics of the studies in terms of year of publication and forum of publication, these results provide an overview of the research in this area.

3.1 Publication years and forums

The studies on climate change gamification started around year 2011, while increasing in number after 2013, with a peak on 2015, and a constant interest holding so far in 2018. The studies are published in various journals and conferences, that can be categorized into three main fields: education, environment, and entertainment.

3.2 Research approaches

Regarding the research approaches, first, we analyzed the *research method* identified in the primary study, while also considering the data gathering and evaluation methods. Second, we identified the *theoretical framework* that was used in the primary study, to highlight the theoretical lenses that have been used in the climate change gamification literature. The analysis of the research approach was done for answering the first research question (*What research approaches are employed for studying gamification of climate change engagement?*) and for performing the quality appraisal¹ of the studies to identify the strength of evidence on how successful gamification is for climate change engagement.

Most of the studies framed the research within a learning or educational theoretical background. The empirical studies in our review employed especially qualitative research approaches (7 studies of which 6 are case studies). The next most popular approaches were mixed methods and quantitative approaches, with 3 studies each. Among the reviewed studies, one article was a systematic literature review of 43 primary studies (see Flood et al. [25]). We included this study in the review, as it provides a high strength of evidence that serious games are successful in engagement and decision making of climate change adaptation. However, their study differs from ours in that they focus only on adaptation and serious games; only two studies in our study are reviewed in [25]. While [25] employed more search databases, the higher number of articles retrieved is also due to the different inclusion and exclusion criteria. We have retained only conference and journal articles which addressed the climate change engagement, while [25] included also 8 reports, working papers and book chapters. They included

¹ Quality appraisal is a step in the SLR that is used to assess the strength of evidence provided by a study to answer a research question based on the research method and the nature of the data and data analysis (see [17,35]).

also studies on other environmental topics than climate change, such as watershed management and livestock systems.

To assess the reliability and validity of the results, we investigated the sources of *data* (data gathering, data analysis procedures, the amount of data), based on which we assessed the *strength of evidence* (i.e., how strongly one can rely on the results using own hierarchy of evidence, see [17,35]). As outlined by Aveyard [17], for assessing the strength of evidence, we considered the amount and quality of the data in the study and categorized the studies into either *High*, *Medium* or *Low* strength of evidence, according to our own hierarchy of evidence relevant to the goals of our literature review. We found that 4 studies provided a high strength of evidence on how gamification is successful in climate change engagement; one SLR study, two controlled experiments, and one study of multiple case studies (see Nussbaum et al. [5], Flood et al. [25], Ouriachi et al. [23], and Parker et al. [26]).

3.3 Climate change gamification

To answer the second research question, we analyzed the results and the context in each primary study to identify interesting contexts of successful gamification. We have identified the *type of gamification* used in the study (e.g., type of game, serious game, gamification) to have an overview on what types of gamification have been applied to the climate change context. We employed the taxonomy proposed by Eliëns et al. [36] and categorized the *focus* of the climate change gamification studies. Accordingly, we describe the studies in terms of *pathos* (informing the player about the climate change and its consequences using emotional clues), *ethos* (challenging the player how to become climate-correct), and *logos* (presenting the player with climate facts such as prediction models for simulation). Finally, we summarized the *results* of the study in terms of success, to obtain an overview of the results and cross-analyze with other study dimensions such as focus, frame and methodology.

Studies varied with respect to the media employed, thus, not only digital games are implemented, but also physical, such as board games, and social gameplay. These have been found to be surprisingly effective in eliciting the desired behavior. Generally, all studies showed positive results of gamification, with two exceptions. One study (Ouriachi et al. [23]), using a controlled experiment has failed to show significant differences between the control group and experimental group exposed to gamification. Another study (Seebauer [32]), using quantitative research approach to evaluate the educational function of a quiz-type game, showed partial success of gamification; some aspects of gamification were not found effective in the entertainment function of the game, and thus partially failing to elicit engagement with the game. In the next section, implications of the findings are discussed.

4 Discussion and Conclusions

The SLR provided us with a characterization of studies that address gamification for climate change engagement. The reviewed studies varied with respect to their research methods but were mostly framed within a learning theoretical background. The studies

addressed games that were implemented using various media and technologies (digital, physical, social). They focused on various climate change responses (i.e., adaptation and mitigation), various foci (ethos, logos, and pathos), and various target participants.

The findings show that climate change gamification is a research area that deserves more attention from researchers as there is only a limited number of studies addressing this important issue. Our literature review indicates thus that more studies are necessary to advance the research area and in the following we provide a research agenda with specific directions to follow.

The selected climate change gamification studies were published in a wide variety of publication forums; generally classified as environmental research, education, and entertainment. To consolidate climate change gamification research, the studies could be explicitly directed to specific publication forums and could adopt a more dialogical approach through cross-referencing and incremental development. One of the contributions of this study is that it provides a starting point for this incremental development in climate change gamification, by identifying characteristics of the studies, the degree of success, and the strength of evidence of the results. The reported cross-perspective of the dimensions of the studies provides an assessment of what limitations there are in the current knowledge and what can be done to contribute to the research area.

Studies with high strength of evidence form the foundation upon which new theories and hypotheses can be built. A small number of studies with control groups is problematic for a reliable assessment of the success of climate change gamification. Thus, more experimental studies are needed to establish the effectiveness of gamification in climate change engagement. The findings in this respect indicate that advancing the climate change gamification as a field of study is slow, but the trend is promising. However, longitudinal studies were missing from the employed approaches, while these are especially needed to assess to what extent the learned skills are applied in real life.

Regarding the climate change gamification focus, many studies had two or more different foci to address climate change engagement. Many of the games assumed the informative and emotional function (pathos), ethical function (ethos), and decision-making and behavioral changing function (logos) of the climate change communication. We recommend all three functions to be addressed in the gamification, for the communication to be effective and triggering engagement.

The state of the art best practices of climate change gamification highlights the success of non-digital games. This can be studied further to investigate what makes them successful when compared to digital games, as well as to build and evaluate digital games that borrow these successful factors from non-digital games.

In summary, research in this area is relatively sparse, however, most of the studies show to some degree of evidence the success of gamification in climate change communication and engagement. This paper reviewed the existing research and identified empirical findings, as well as conceptual and methodological bases upon which to build further studies and propose novel research agendas and approaches for climate change gamification. The review identified theoretical frameworks used to approach climate change communication and education through gamification. The results of this study showed that gamification is an effective tool for engaging with diverse stakeholders and to enable learning, changes in public policy, and behavioral change.

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*Primary studies are marked with * in the reference list.*

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