PROCEEDINGS OF ASIA DESIGN AND INNOVATION CONFERENCE
5–6 DECEMBER, 2024, SHANGHAI, CHINA

A BIBLIOMETRIC REVIEW OF RESEARCH ON GAMIFICATION USED IN ENVIRONMENTAL PROTECTION, 2014-2024

Qianrong Li[1] **, Chenyu Zhang**[1] **and Ruiyi Jiang**[2]
[1]Hubei Institute of Fine Arts
[2]Harbin Institute of Technology

ABSTRACT
This study presents a bibliometric analysis of the research trends and applications of gamification technology in the field of environmental protection between 2014 and 2024. Addressing critical environmental challenges such as climate change, resource depletion, and biodiversity loss, gamification has emerged as an innovative approach to enhance public engagement in sustainability. By incorporating game-like motivational mechanisms into non-game contexts, gamification has proven effective in fostering behavioral changes in areas like energy conservation, water management, and ecological restoration. Utilizing tools such as VOSviewer and CiteSpace, this study analyzes collaboration networks, citation patterns, and emerging trends, with a particular focus on the integration of immersive technologies like virtual and augmented reality. The findings highlight key applications of gamification in environmental protection and suggest practical implications for policymakers and practitioners seeking to design more engaging environmental initiatives. Furthermore, the study identifies the potential for immersive technologies to enhance environmental awareness and action. Despite these advancements, challenges remain, particularly in adapting gamification strategies to diverse demographic groups and sustaining long-term behavioral changes. The study concludes with recommendations for future research, including the need for large-scale evaluations and the exploration of the synergy between gamification and emerging technologies to maximize the impact on public engagement in environmental sustainability.

Keywords: *Gamification, Environmental Protection, Bibliometric Analysis,Serious Games, Energy Conservation*

1 INTRODUCTION

The increasingly severe environmental challenges, such as climate change and biodiversity loss, necessitate innovative approaches to engage the public in sustainable practices. Traditional environmental education methods often fail to sustain long-term public interest and action, highlighting the need for interactive technological solutions. For instance, mobile augmented reality and gamification have been shown to improve students' environmental knowledge and awareness, encouraging greater involvement in environmental issues [1]. Furthermore, public sector innovation aimed at addressing environmental challenges often faces obstacles such as limited resources and governance issues, which may hinder effective implementation [2]. The role of community initiatives and environmental NGOs is also critical in promoting public engagement and raising awareness [3]. Integrating technology into environmental education can significantly enhance public participation, foster a deeper understanding of sustainability issues, and ultimately lead to more proactive environmental behavior [4]. Thus, employing innovative educational technologies and promoting community involvement are essential strategies for maintaining public interest in environmental protection efforts.

Gamification, by integrating game elements such as points, rewards, and leaderboards into non-game environments, has become a powerful tool for enhancing public environmental awareness and behavior. This approach has demonstrated its effectiveness in various fields, including energy management and water conservation, successfully motivating individuals to adopt sustainable practices [5][6]. For example, Madani et al. illustrated how serious games can significantly improve public understanding of environmental management, leading to tangible pro-environmental behaviors[7]. Empirical studies

further support the effectiveness of gamification in fostering both intrinsic and extrinsic motivation. The Self-Determination Theory (SDT) explains how gamification fulfills individuals' needs for autonomy, competence, and relatedness, thereby enhancing intrinsic motivation and sustaining long-term engagement with environmental initiatives [8][9]. Overall, gamification represents a promising strategy for encouraging public participation in environmental protection efforts.

Despite the extensive exploration of gamification technology in existing studies, several challenges and limitations remain. First, further research is needed to understand how current gamification designs can be adapted to meet the needs of diverse groups, ensuring they effectively stimulate user engagement across different demographics. Variations in age, cultural background, and educational levels affect how individuals respond to gamification mechanisms, necessitating the design of more targeted and flexible gamification strategies. Second, most research to date has focused on small-scale or short-term experiments, with a lack of systematic evaluations on large-scale, long-term behavior change. Thus, exploring how gamification can sustain public participation in environmental actions and foster lasting behavior change in real life is a critical direction for future research. Additionally, with the rise of emerging technologies such as virtual reality (VR) and augmented reality (AR), investigating how these technologies can be integrated with gamification to enhance public engagement and behavior change has become a growing area of interest.

Based on these challenges, the primary objective of this study is to systematically review the application of gamification in the field of environmental protection over the past decade (2014-2024) using bibliometric methods, to identify research hotspots and future trends, and to explore how gamification can encourage public participation in environmental behaviors and sustainable development actions. Specifically, this study will address the following research questions:

1. What are the main application scenarios and research hotspots of gamification in the field of environmental protection?
2. How does gamification technology promote public engagement in environmental protection and associated behavior change?
3. How have citation patterns and research trends in the literature evolved, particularly regarding the integration of emerging technologies such as virtual reality and augmented reality with gamification?

This paper will employ bibliometric analysis tools, such as VOSviewer and CiteSpace, to systematically review relevant research from 2014 to 2024, identifying current research hotspots and trends, and proposing directions for future research. Through a comprehensive analysis of the role of gamification in environmental protection, this study aims to provide new insights into promoting long-term public engagement in environmental actions and advancing sustainable development.

2 METHOD

This study adopts bibliometric analysis in order to reveal the current status and future development trend of gamification technology application in the field of environmental protection. To ensure the breadth and academic authority of the data, Web of Science and Google Scholar were chosen as the main data sources for this study, and the bibliometric tools VOSviewer and CiteSpace were applied to visualise and analyse the data. Three key visualisation data were included in the study: (1)keyword co-occurrence analysis, (2)citation emergence detection, (3)time-evolving pattern recognition. The study aims to systematically reveal the research hotspots in the field as well as the analysis of future trends. The results of the study provide a comprehensive academic overview of gamification applications in environmental protection, as well as an important reference value for future research directions.

Based on bibliometric analysis, this study aims to systematically sort out and summarise the current status and future development trend of the application of gamification technology in the field of environmental protection. The advantage of the bibliometric method is that it can reveal research areas that have not been fully explored through objective data, and provide scientific direction guidance for future research. This method is particularly effective in interdisciplinary research, which can avoid the bias of subjective assessment by researchers and provide a more comprehensive analysis perspective(see Figure 1).

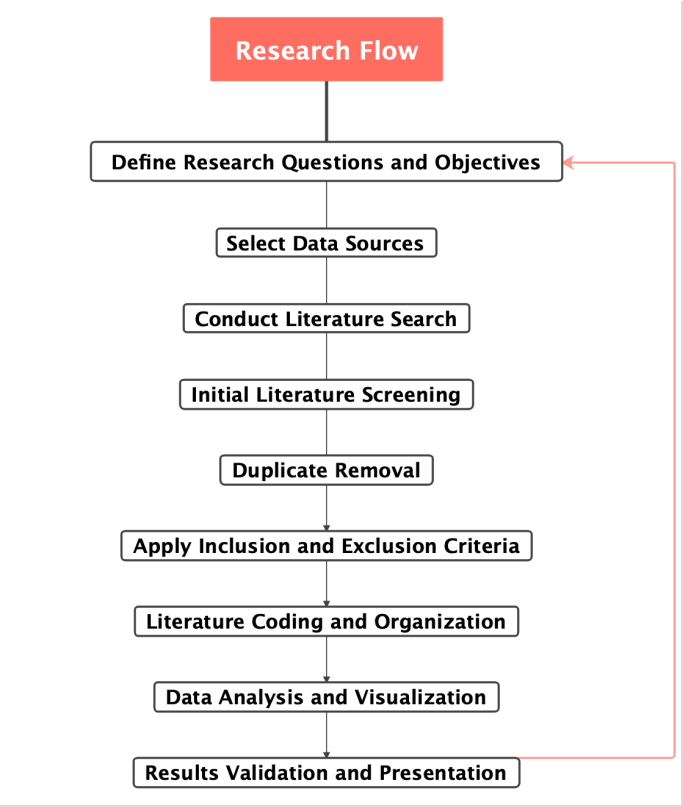

Figure 1. Research Flow

2.1 Search Strategy

During the data collection process, a detailed literature search strategy was designed to ensure that all key literature related to gamification technology and environmental protection was covered. Web of Science and Google Scholar were chosen as the data sources, which not only cover a wide range of topics, but also provide a large amount of peer-reviewed, high-quality literature, providing a solid data base for the study and ensuring that the data are academically rigorous and comprehensive. we set a timeframe of 2014 to 2024, aiming to capture the trend of gamification technology in the field of environmental protection over the past decade. To ensure the academic rigour and empirical validity of the data, the types of literature screened for inclusion were limited to journal articles, review papers, and conference papers, with a focus on empirical analysis studies of academic value.

In the literature search, multiple keyword combinations were used to cover gamification-related topics (e.g., ‘gamification’, ‘serious games’, ’ interactive games’, “game-based learning”) and environmental protection related topics (e.g., ’ environmental protection ’, ‘sustainability’, ‘climate change’, ‘energy conservation ’, ‘pollution control’). In the Web of Science database, the specific search formula is:

TS=(‘gamification ’ OR ‘serious games ’ OR ‘interactive games ’ OR ‘game-based learning ’) AND TS=(‘environmental protection ’ OR ‘sustainability ’ OR ’ climate change ‘ OR “energy conservation ” OR “pollution control ”) AND PY=(2009-2024) AND DT=(’ Article ’ OR “Conference Paper ”).

This search formula resulted in an initial 570 documents. Then, after subject relevance filtering, the filtering result was 299 articles. In Google Scholar, using a similar advanced search strategy, 502 articles were obtained and 202 articles were retained after further screening. Subsequently, an initial screening based on the titles and abstracts of the literature excluded literature that was not relevant to the study topic, especially those that only explored education or business management but did not address environmental protection. Eventually, after further screening, 299 documents were retained in Web of Science and 202 in Google Scholar.

To ensure the uniqueness of the literature, the screened literature was de-weighted using the literature management tool Zotero. After de-weighting, the final included dataset contained 457 documents. Next,

the literature was further screened and processed based on explicit inclusion and exclusion criteria. The inclusion criteria included that the literature should be related to the application of gamification in the fields of environmental protection, sustainable development, climate change, energy saving or pollution control, and only journal articles, conference papers and review papers published between 2014 and 2024 were included to ensure that the literature had internationalisation and academic impact. At the same time, literature with inconsistent themes, non-academic literature, short literature with abstracts only, and literature that is biased towards medicine, chemistry, and other literature that is not directly related to the cross-cutting applications of gamification and environmental protection were excluded.

- Inclusion Criteria
  – The literature should discuss the application of gamification technology or interaction design in environmental protection, sustainable development, or climate change.
  – The literature should include empirical research, such as the application of gamification technology in specific environmental protection projects or empirical analysis of user behavior.
  – The literature should be academic journal articles or conference papers to ensure academic rigor and scientific quality.
- Exclusion Criteria
  – Studies that focus solely on energy-saving education without directly addressing the broader application of environmental protection.
  – Research that mainly discusses workplace gamification for efficiency improvement, which does not focus on environmental protection.
  – Literature that concentrates on climate change risk management or digital transformation without in-depth exploration of gamification applications.
  – Studies related to traffic management or food systems, which do not focus on the direct impact of gamification on environmental protection
  .....

After rigorous screening, a total of 213 literatures were finally included in the data analysis. In order to systematically process and analyse these documents, we coded the documents using Excel and Zotero, and the coding fields included information such as document title, author, year of publication, keywords, DOI, number of citations, and the name of the journal or conference in which the document was published. These literature organisation and coding laid a solid data foundation for the subsequent analysis.

2.2 Data Analysis

After completing the literature de-duplication and screening process, the study entered the literature network analysis phase. With the help of bibliometric analysis tools such as VOSviewer and CiteSpace, key hotspots and trends in the field were systematically revealed. This phase began with a keyword co-occurrence analysis using VOSviewer to identify high-frequency keywords and their co-occurrence relationships, helping to identify important topics and concerns in the study. In this way, high-frequency co-occurrences of certain concepts can be clearly identified, revealing key themes in the field of gamification and environmental protection. For example, “environmental sustainability”, “user engagement”, “behavioral change”, and “incentives” may be high-frequency keywords.

The keyword co-occurrence analysis not only demonstrates the core issues that researchers are concerned with in this field, but also reflects the intersection and collaboration of different disciplinary fields, showing how gamification technology can be combined with behavioral science, psychology, pedagogy, and other disciplines to provide innovative solutions for environmental protection. By analyzing the co-occurrence relationships between keywords, researchers can better understand the intrinsic connections between different concepts, reveal the importance of interdisciplinary collaboration, and help identify future research directions.

In addition, a citation emergence analysis was conducted through CiteSpace in order to further explore the academic frontier. This analysis identifies key documents with a significant increase in citation frequency within a specific time period, revealing important research breakthroughs and hot topics in the field. By analyzing citation bursts, researchers are able to identify certain studies that have gained a high level of academic attention within a short period of time, indicating that these literatures have made significant contributions to advancing the field. For example, within certain time frames, there may be prominent studies that explore how gamification can motivate users to adopt more environmentally friendly behaviors in their daily lives, or how interactive systems can be designed to drive public

awareness of sustainability. This analysis provides a dynamic perspective on research that can help understand how academic hotspots evolve in response to technological developments and changing societal needs.

In addition to keyword co-occurrence analysis and citation emergence analysis, time evolution analysis was also used. This analysis reveals changes in research focus over time by generating a timeline showing the evolution of gamification technologies in environmental protection. For example, early research may have focused more on basic interaction design and user behavioral changes, while over time, research has gradually evolved toward how to more effectively promote environmental protection actions through the application of refined game mechanics, and smart devices. This time-dimensional analysis helps researchers better understand the development trajectory of the field and possible future research directions, providing a reference basis for the next academic work.

In order to verify the accuracy and consistency of the analysis results, the keyword co-occurrence and citation emergence analyses were repeated at various stages, and cross-validation was performed to ensure the reliability of the data. Intuitive visualization diagrams were generated using tools such as VOSviewer and CiteSpace, which provide a clear picture of the key issues in the research area as well as an analysis of trends in future research.

3 RESULTS

Through a comprehensive bibliometric analysis of literature from 2014 to 2024, this study identifies major trends and research hotspots in the application of gamification within the field of environmental protection. Using tools such as VOSviewer and CiteSpace, the study conducted keyword co-occurrence, citation burst, and timeline analyses.

3.1 Keywords Co-occurrence Analysis

The analysis highlights the prominence of keywords such as gamification, serious games, and sustainability within the research network (see Figure 2). These terms frequently co-occur with concepts like **behavior change**, **social interaction**, and **pro-environmental behavior**, demonstrating the focus on utilizing gamification to foster public engagement and modify environmental behaviors. For instance, gamified applications incorporating **point systems**, **rewards**, and **interactive tasks** have been shown to enhance user motivation in adopting environmentally responsible actions. Moreover, the strong association between **sustainability** and **pro-environmental behavior** further underscores the potential of gamification in promoting sustainable practices at both individual and community levels. The significant co-occurrence of **education** with these key terms also points to the widespread use of gamification in **environmental education**, where **serious games** provide simulated environments for users to learn and apply environmental knowledge in real-world contexts.

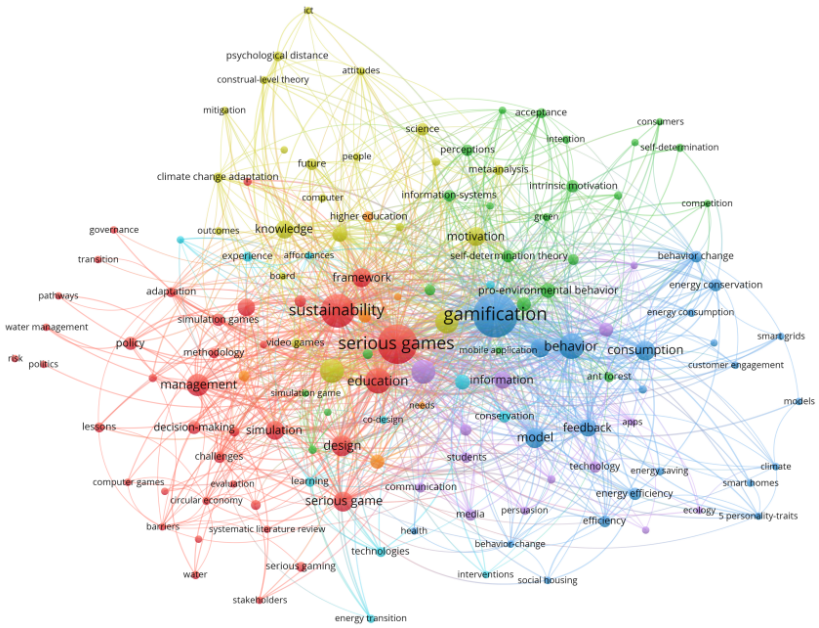

Figure 2. Keywords Co-occurrence

3.2 Citation Burst Analysis

The citation burst analysis identifies pivotal studies that have significantly influenced research on gamification and serious games since 2014. Notable publications, such as Hamari (2014) and Connolly (2012), have been instrumental in shaping the application of gamification in both education and environmental protection (see Figure 3). Hamari's (2014) work investigates the impact of gamification on user behavior, providing empirical evidence that highlights gamification's potential to drive environmental behavior change by enhancing user engagement and motivation. Similarly, Orland et al. (2014) explore the role of gamification in promoting energy conservation within buildings, demonstrating how virtual environments can educate users on energy-saving practices. These citation bursts underscore the expanding application of gamification, emphasizing its broader social and environmental implications beyond conventional domains like entertainment and education.

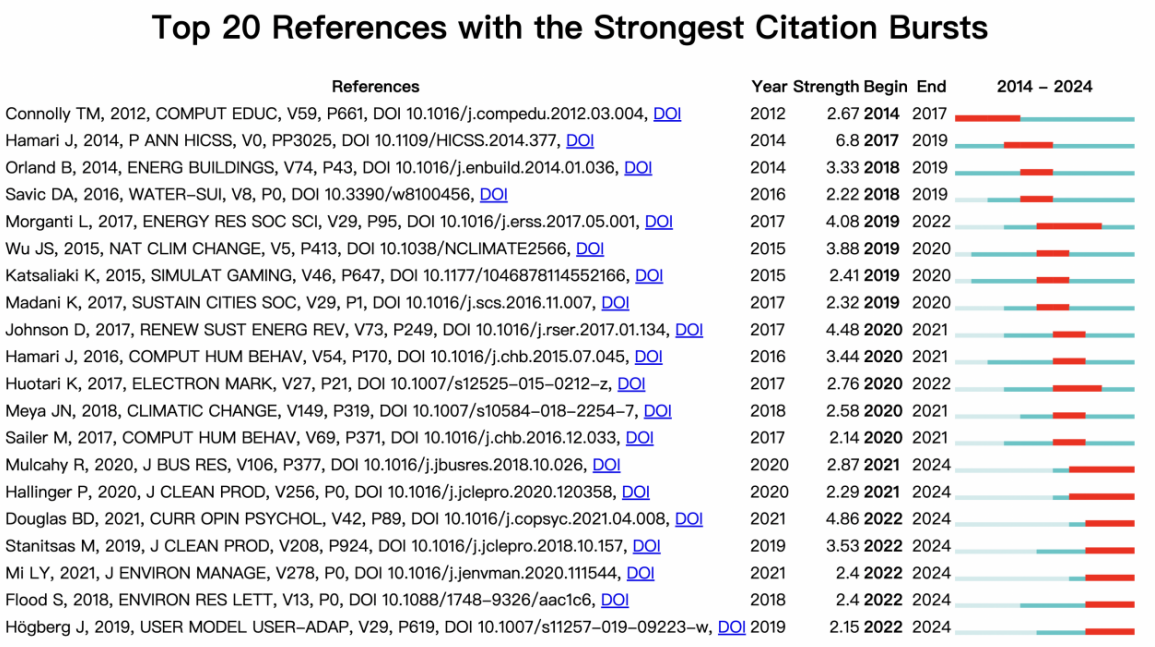

Figure 3. Citation Bursts

3.3 Timeline Analysis

The timeline analysis reveals that since 2017, the integration of energy conservation and virtual reality technologies has emerged as a significant research trend in the field of environmental protection (see Figure 4). The increasing occurrence of keywords like energy conservation and virtual reality reflects growing interest in utilizing these technologies together. The prominence of energy conservation suggests a focus on leveraging gamification to improve energy management practices. Virtual reality, as an emerging technology, enhances the immersive experience, allowing users to visualize the consequences of energy wastage, thus encouraging behavioral change. Additionally, the rising frequency of augmented reality points to its recognized potential in environmental education and behavior modification, where users can simulate real-world environmental challenges in virtual environments.

3.4 Multidisciplinary Applications of Gamification in Environmental Protection

The experimental data underscore the broad application of gamification across various environmental protection domains, particularly in energy conservation, ecological restoration, and water resource management. Keywords such as energy conservation and energy efficiency frequently appear in the literature, signaling the significant role of gamification in these areas.

The strong association between gamification and behavior change in the context of energy conservation suggests that researchers are focusing on how gamified systems can foster sustainable energy behaviors in daily life. For example, platforms like Smartege simulate energy-saving activities within virtual

environments, educating users on efficient energy use. Gamification systems also support community-level initiatives, such as promoting the adoption of renewable energy.

In the area of water management, keywords like water conservation highlight gamification's potential in encouraging the efficient use and management of water resources. Although less frequently discussed, the combination of ecological restoration and gamification presents opportunities for public engagement in virtual ecological restoration tasks, offering interactive learning experiences and practical skills that can be applied to real-life conservation efforts.

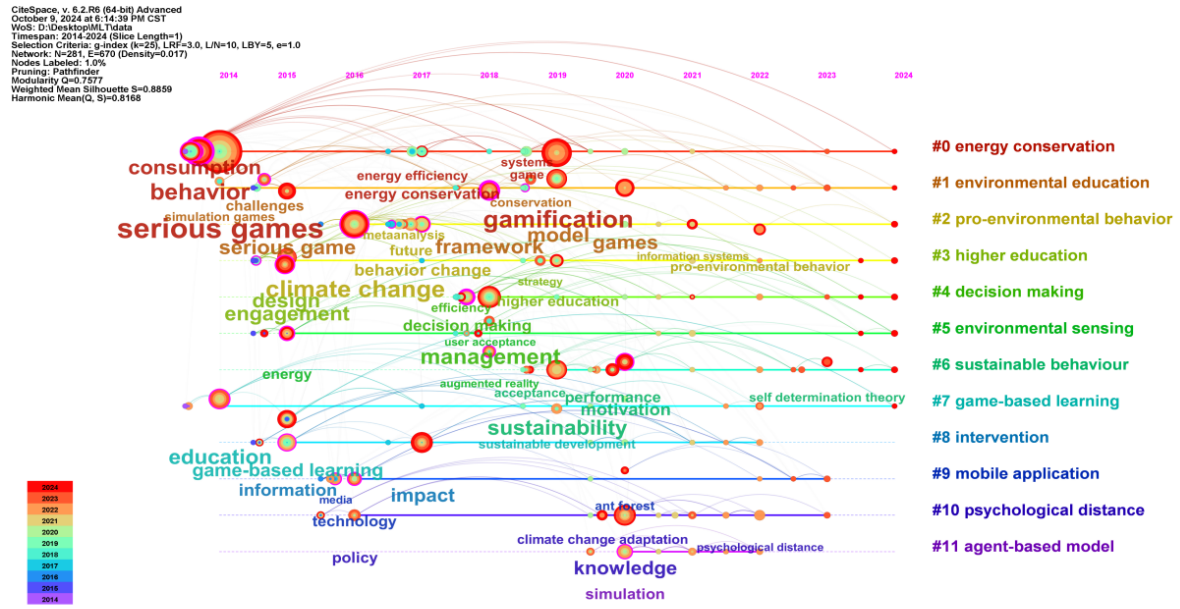

Figure 4. Timeline

3.5 Public Engagement and Social Impact

Gamification has proven to be an effective tool for enhancing public engagement and generating social impact in environmental actions. The high frequency of engagement in the keyword co-occurrence analysis highlights public participation as a key objective of gamified applications. By increasing users' sense of involvement, gamified platforms, such as community-based energy conservation apps, have significantly boosted participation in energy-saving behaviors through competitive elements like leaderboards and rewards.

Furthermore, the strong association between social interaction and engagement indicates that gamification frequently integrates social features such as progress sharing, team collaboration, and community challenges. These elements further enhance public participation, particularly in collective environmental initiatives, by fostering a sense of community and shared responsibility.

3.6 Emerging Trends: Virtual Reality and Augmented Reality

The integration of virtual and augmented reality with gamification has seen significant growth since 2018, as indicated by the increasing frequency of these keywords in the literature. Immersive technologies, such as virtual reality, when combined with gamified environments, allow users to directly experience environmental challenges, such as ecosystem degradation. This immersive experience fosters a stronger sense of environmental responsibility and promotes behavior change.

The expanding application of augmented reality further enhances user interaction with real-world environmental challenges by superimposing virtual information onto physical surroundings. This approach provides innovative ways to engage users in sustainability actions, enabling them to interact with environmental data in real time and encouraging more effective environmental behaviors.

4 CONCLUSION

This study provides a comprehensive bibliometric analysis of the application of gamification in the field of environmental protection, focusing on the evolving research trends, key areas of impact, and future directions. The findings demonstrate that gamification, through its interactive and motivational

mechanisms, has proven effective in enhancing public engagement with environmental issues, particularly in areas like energy conservation, water management, and ecological restoration.

The study identified gamification, serious games, and sustainability as central concepts, with an increasing focus on behavior change and social interaction. These elements are vital in driving public participation and fostering long-term commitment to sustainable practices. Moreover, the integration of virtual reality (VR) and augmented reality (AR) with gamification has emerged as a significant trend since 2017, offering immersive experiences that can enhance the effectiveness of environmental education and behavior change initiatives.

While the application of gamification has gained traction, there are several areas for future exploration. First, the long-term impact of gamification on sustained behavior change, particularly in large-scale initiatives, requires more comprehensive evaluation. Second, adapting gamification strategies to suit diverse demographic groups is essential, as cultural and educational differences influence the effectiveness of these interventions. Finally, the growing synergy between gamification and emerging technologies like VR and AR presents a promising avenue for creating more engaging and impactful environmental solutions.

In conclusion, gamification holds significant potential in addressing environmental challenges by promoting public engagement and facilitating sustainable behavior change. Future research should focus on optimizing these technologies, exploring their broader applications, and investigating their long-term effects on public involvement in environmental protection.

REFERENCES

[1] Mei, B., and Yang, S. *Nurturing Environmental Education at the Tertiary Education Level in China: Can Mobile Augmented Reality and Gamification Help?* Sustainability, 2019, 11(16), 4292.

[2] Pratama, M. R., Prasetya, A., Rahimah, A., and Prakasa, Y. *Does the Environment Matter? Assessing Indonesia Public Service Innovation towards Environmental Issues*, 2023, pp. 127-135.

[3] Dong, N. *Investigate the Role of Environmental NGOs in Global Sustainable Development and Environmental Governance.* Scientific and Social Research, 2024, 6(5), 157-163.

[4] Maipas, S., Konstantinidou, A., Lazaris, A. C., and Kavantzas, N. *Environmental Health Education: From Museum Specimens and Math Word Problems to Virtual and Augmented Reality.* Environmental Health Insights, 2021, 15.

[5] Wang, X., and Yao, X. *Fueling Pro-Environmental Behaviors with Gamification Design: Identifying Key Elements in Ant Forest with the Kano Model.* Sustainability, 2020, 12(6), 2213.

[6] Huang, M., Saleh, M. I., and Zolkepli, I. A. *Gamification as a Learning Tool for Pro-Environmental Behavior: A Systematic Review.* Malaysian Journal of Social Sciences and Humanities (Mjssh), 2022, 7(12), e001881.

[7] Madani, K., Pierce, T., and Mirchi, A. *Serious Games on Environmental Management.* Sustainable Cities and Society, 2017, 29, 1–11.

[8] Sun, Y., and Xing, J. *The Impact of Gamification Motivation on Green Consumption Behavior—An Empirical Study Based on Ant Forest.* Sustainability, 2022, 15(1), 512.

[9] Huang, M., Saleh, M. I., and Zolkepli, I. A. *The Moderating Effect of Green Advertising on the Relationship between Gamification and Sustainable Consumption Behavior: A Case Study of the Ant Forest Social Media App.* Sustainability, 2023, 15(4), 2883.

[10] Hallinger, P., Wang, R., Chatpinyakoop, C., Nguyen, V.-T., and Nguyen, U.-P. *A Bibliometric Review of Research on Simulations and Serious Games Used in Educating for Sustainability, 1997–2019.* Journal of Cleaner Production, 2020, 256, 120358.

[11] Konstantakopoulos, I. C., Barkan, A. R., He, S., Veeravalli, T., Liu, H., and Spanos, C. *A Deep Learning and Gamification Approach to Improving Human-Building Interaction and Energy Efficiency in Smart Infrastructure.* Applied Energy, 2019, 237, 810–821.

[12] Iria, J., Fonseca, N., Cassola, F., Barbosa, A., Soares, F., Coelho, A., and Ozdemir, A. *A Gamification Platform to Foster Energy Efficiency in Office Buildings.* Energy and Buildings, 2020, 222, 110101.

[13] Cellina, F., Bucher, D., Mangili, F., Veiga Simão, J., Rudel, R., and Raubal, M. *A Large Scale, App-Based Behaviour Change Experiment Persuading Sustainable Mobility Patterns: Methods, Results and Lessons Learnt.* Sustainability, 2019, 11(9), 2674.

[14] Kramer, J., and Petzoldt, T. *A Matter of Behavioral Cost: Contextual Factors and Behavioral Interventions Interactively Influence Pro-Environmental Charging Decisions.* Journal of

Environmental Psychology, 2022, 84, 101878.
[15] Evans, B., Khoury, M., Vamvakeridou-Lyroudia, L., Chen, O., Mustafee, N., Chen, A. S., Djordjevic, S., and Savic, D. *A Modelling Testbed to Demonstrate the Circular Economy of Water.* Journal of Cleaner Production, 2023, 405, 137018.
[16] Teran-Escobar, C., Becu, N., Champollion, N., Gratiot, N., Hingray, B., Panthou, G., and Ruin, I. *A Pilot Randomised Controlled Trial Comparing the Effectiveness of the MaTerre180' Participatory Tool Including a Serious Game versus an Intervention Including Carbon Footprint Awareness-Raising on Behaviours among Academia Members in France.* PLoS ONE, 2024, 19(3), e0301124.
[17] Agusdinata, D. B., Lukosch, H., Hanif, M., and Watkins, D. *A Playful Approach to Household Sustainability: Results from a Pilot Study on Resource Consumption.* Simulation & Gaming, 2023, 54(1), 104–130.
[18] Rottondi, C., and Verticale, G. *A Privacy-Friendly Gaming Framework in Smart Electricity and Water Grids*. IEEE Access, 2017, 5, 14221–14233.
[19] Mittal, A., Scholten, L., and Kapelan, Z. *A Review of Serious Games for Urban Water Management Decisions: Current Gaps and Future Research Directions.* Water Research, 2022, 215, 118217.
[20] Aubert, A. H., Bauer, R., and Lienert, J. *A Review of Water-Related Serious Games to Specify Use in Environmental Multi-Criteria Decision Analysis.* Environmental Modelling & Software, 2018, 105, 64–78.
[21] Orduña Alegría, M. E., Schütze, N., and Zipper, S. C. *A Serious Board Game to Analyze Socio-Ecological Dynamics Towards Collaboration in Agriculture.* Sustainability, 2020, 12(13), 5301.
[22] Khoury, M., Gibson, M. J., Savic, D., Chen, A. S., Vamvakeridou-Lyroudia, L., Langford, H., and Wigley, S. *A Serious Game Designed to Explore and Understand the Complexities of Flood Mitigation Options in Urban–Rural Catchments.* Water, 2018, 10(12), 1885.
[23] Ouariachi, T., and Elving, W. *Accelerating the Energy Transition Through Serious Gaming: Testing Effects on Awareness, Knowledge and Efficacy Beliefs.* ECEL, 2020, 18(5), 410–420.
[24] Fischer, S., Göhlich, M., and Schmitt, J. *Adapting to Climate Change Through Play? Didactically Effective Elements of a Business Simulation Game.* Front. Educ., 2024, 9, 1303107.
[25] Taleb, M. S., Belayutham, S., and Ibrahim, C. K. I. C. *Applications of Serious Games in Construction: The Current State, Classifications and a Proposed Process Framework.* International Journal of Construction Management, 2023, 23(10), 1726–1736.
[26] Diniz Dos Santos, A., Strada, F., and Bottino, A. *Approaching Sustainability Learning Via Digital Serious Games.* IEEE Trans. Learning Technol., 2019, 12(3), 303–320.
[27] Latham, Z., Barrett-Lennard, G., and Opdyke, A. *Archetypes of Local Governance for Flood Risk Reduction Decision-Making under Uncertain Climate Change Futures.* Sustainable Cities and Society, 2024, 112, 105632.
[28] Luzzati, T., Mura, E., Pellegrini, L., Raugi, M., Salvati, N., Schito, E., Scipioni, S., Testi, D., and Zerbino, P. *Are Energy Community Members More Flexible than Individual Prosumers? Evidence from a Serious Game.* Journal of Cleaner Production, 2024, 444, 141114.
[29] Abad, J., Booth, L., Baills, A., Fleming, K., Leone, M., Schueller, L., and Petrovic, B. *Assessing Policy Preferences amongst Climate Change Adaptation and Disaster Risk Reduction Stakeholders Using Serious Gaming.* International Journal of Disaster Risk Reduction, 2020, 51, 101782.
[30] Casals, M., Gangolells, M., Macarulla, M., Forcada, N., Fuertes, A., and Jones, R. V. *Assessing the Effectiveness of Gamification in Reducing Domestic Energy Consumption: Lessons Learned from the EnerGAware Project.* Energy and Buildings, 2020, 210, 109753.
[31] Keeler, L., Bernstein, M., Nelson, J., and Kay, B. *AudaCITY: A Capacity-Building Research Method for Urban Sustainability Transformation.* Frontiers in Sustainable Cities, 2022, 4.
[32] Cellina, F., Bucher, D., Simão, J., Rudel, R., and Raubal, M. *Beyond Limitations of Current Behaviour Change Apps for Sustainable Mobility: Insights from a User-Centered Design and Evaluation Process.* Sustainability, 2019, 11(8).
[33] Rodríguez, N., Yebra, F., Dopico, A., Garcia-Vazquez, E., and Dopico, E. *Blue Gold, Game-Based Learning to Encourage Sustainable Consumption: The Case of Mobile Phones.* Sustainability, 2024, 16(2).
[34] Huotari, K., and Hamari, J. *A Definition for Gamification: Anchoring Gamification in the ServiceMarketing Literature.* Electron Markets, 2017, 27(1), 21–31.
[35] Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., and Boyle, J. M. *A Systematic Literature*

Review of Empirical Evidence on Computer Games and Serious Games. Computers & Education, 2012, 59(2), 661–686.
[36] Flood, S., Cradock-Henry, N. A., Blackett, P., and Edwards, P. *Adaptive and Interactive Climate Futures: Systematic Review of 'Serious Games' for Engagement and Decision-Making.* Environmental Research Letters, 2018, 13(6), 063005.
[37] Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., and Edwards, T. *Challenging Games Help Students Learn: An Empirical Study on Engagement, Flow and Immersion in Game-Based Learning.* Computers in Human Behavior, 2016, 54, 170–179.
[38] Wu, J. S., and Lee, J. J. *Climate Change Games as Tools for Education and Engagement.* Nature Climate Change, 2015, 5(5), 413–418.
[39] Mulcahy, R., Russell-Bennett, R., and Iacobucci, D. *Designing Gamified Apps for Sustainable Consumption: A Field Study.* Journal of Business Research, 2020, 106, 377–387.
[40] Hamari, J., Koivisto, J., and Sarsa, H. *Does Gamification Work? – A Literature Review of Empirical Studies on Gamification.* In 2014 47th Hawaii International Conference on System Sciences, 2014, pp. 3025–3034.
[41] Katsaliaki, K., and Mustafee, N. *Edutainment for Sustainable Development.* Simulation & Gaming, 2014.
[42] Meya, J. N., and Eisenack, K. *Effectiveness of Gaming for Communicating and Teaching Climate Change.* Climatic Change, 2018, 149(3), 319–333.
[43] Stanitsas, M., Kirytopoulos, K., and Vareilles, E. *Facilitating Sustainability Transition through Serious Games: A Systematic Literature Review.* Journal of Cleaner Production, 2019, 208, 924–936.
[44] Högberg, J., Hamari, J., and Wästlund, E. *Gameful Experience Questionnaire (GAMEFULQUEST): An Instrument for Measuring the Perceived Gamefulness of System Use.* User Modeling and User-Adapted Interaction, 2019, 29(3), 619–660.
[45] Johnson, D., Horton, E., Mulcahy, R., and Foth, M. *Gamification and Serious Games within the Domain of Domestic Energy Consumption: A Systematic Review.* Renewable and Sustainable Energy Reviews, 2017, 73, 249–264.
[46] Douglas, B. D., and Brauer, M. *Gamification to Prevent Climate Change: A Review of Games and Apps for Sustainability.* Current Opinion in Psychology, 2021, 42, 89–94.
[47] Morganti, L., Pallavicini, F., Cadel, E., Candelieri, A., Archetti, F., and Mantovani, F. *Gaming for Earth: Serious Games and Gamification to Engage Consumers in pro-Environmental Behaviours for Energy Efficiency.* Energy Research & Social Science, 2017, 29, 95–102.
[48] Sailer, M., Hense, J. U., Mayr, S. K., and Mandl, H. *How Gamification Motivates: An Experimental Study of the Effects of Specific Game Design Elements on Psychological Need Satisfaction.* Computers in Human Behavior, 2017, 69, 371–380.
[49] Mi, L., Xu, T., Sun, Y., Zhao, J., Lv, T., Gan, X., Shang, K., and Qiao, L. *Playing Ant Forest to Promote Online Green Behavior: A New Perspective on Uses and Gratifications.* Journal of Environmental Management, 2021, 278, 111544.
[50] Orland, B., Ram, N., Lang, D., Houser, K., Kling, N., and Coccia, M. *Saving Energy in an Office Environment: A Serious Game Intervention.* Energy and Buildings, 2014, 74, 43–52.
[51] Savic, D. A., Morley, M. S., and Khoury, M. *Serious Gaming for Water Systems Planning and Management.* Water, 2016, 8(10), 456.