

**DIGITAL SERIOUS GAMES FOR CLIMATE CHANGE
EDUCATION:RESEARCH DATA AND FINDINGS**

DOI: 10.26341/issn.2241-4010-2026-10a-10-L02253

Bokolas Vassilis

PhD, Coordinator, Scientific director, XENIOS POLIS, Greece, Neapolis University, Pafos-Cyprus

vbokolas@xeniospolis.gr

Bondar Yurii

Taras Shevchenko National University of Kyiv, Ukraine

bondar1960@knu.ua

Broccatelli Valerio

LIM Srl Unipersonale, Italy

v.broccatelli@limsrl.org

Hordecki Bartosz

Ph.D., Associate Professor, Faculty of Political Science and Journalism, Adam Mickiewicz University, Poland

bartosz.hordecki@amu.edu.pl

Iorio Elaia

LIM Srl Unipersonale, Italy

e.iorio@limsrl.org

Karametou Panagiota

Ph.D., Harokopio University of Athens, Greece

karametou@hua.gr

Katerynych Petro

Ph.D., Assistant Professor, Taras Shevchenko National University of Kyiv, Ukraine

petro.katerynych@knu.ua

Kornieiev Vitalii

D.Sc., Professor, Taras Shevchenko National University of Kyiv, Ukraine

vmkorn@knu.ua

Lorek Artur

MA, Faculty of Political Science and Journalism, Adam Mickiewicz University, Poland

artur.lorek@amu.edu.pl

Marto Anabela

Computer Science and Communications Research Centre, School of Technology and Management, Polytechnic University of Leiria, Portugal

anabela.marto@ipleiria.pt

Mitoula Roido

Professor, Harokopio University of Athens, Greece

mitoula@hua.gr

Nosova Bogdana

Ph.D., Associate Professor, Taras Shevchenko National University of Kyiv, Ukraine
b.nosova@knu.ua

Ribeiro Roberto

Computer Science and Communications Research Centre, School of Technology and Management, Polytechnic University of Leiria, Portugal
roberto.ribeiro@ipleiria.pt

Rodrigues Nuno

Computer Science and Communications Research Centre, School of Technology and Management, Polytechnic University of Leiria, Portugal
nunorod@ipleiria.pt

Sakson-Boulet Anna

Ph.D., Assistant Professor, Faculty of Political Science and Journalism, Adam Mickiewicz University, Poland
anna.sakson@amu.edu.pl

Silva Fernando

Computer Science and Communications Research Centre, School of Technology and Management, Polytechnic University of Leiria, Portugal
fernando.silva@ipleiria.pt

Stamouli Anna-Athina

ATERMON B.V., the Netherlands
a.stamouli@atermon.nl

Tsimpoulis George

Researcher, Harokopio University of Athens, Greece
george.tsimpl@hotmail.gr

Tzika Katerina

Assistant researcher, XENIOS POLIS, Greece
ass.researcher@xeniospolis.gr

Volobuieva Anastasiia

Ph.D., Associate Professor, Taras Shevchenko National University of Kyiv, Ukraine
nastya_v@knu.ua

Abstract

Higher education institutions are increasingly called upon to adopt pedagogical approaches that can help students engage with the complexity, uncertainty, and practical implications of climate change. Digital serious games offer interactive and experiential environments that may support climate change education, yet their integration into higher education remains uneven.

This study examines the current use, adoption, and perceptions of digital serious games for climate change education across six European countries: Poland, Portugal, Greece, Italy, Ukraine, and the Netherlands. Conducted within the framework of the GAME4CHANGE

project, the study employed a transnational mixed-methods design combining questionnaires with focus groups involving educators, academic staff, and relevant stakeholders.

Across the participating contexts, the findings suggest a recurrent discrepancy between generally positive attitudes towards digital serious games and their limited use in teaching practice. Participants most frequently associated this discrepancy with insufficient professional training, limited familiarity with available games, restricted access to suitable resources, difficulties in aligning games with curricula and assessment, and uneven institutional support.

The integrated analysis is organised through a three-gap interpretive framework comprising competence, familiarity, and readiness. The study highlights the need for coordinated professional development, accessible and curriculum-aligned resources, and institutional strategies that position serious games as components of broader pedagogical designs rather than as standalone solutions.

Keywords: digital serious games, climate change education, higher education, digital pedagogy, sustainability, mixed methods

1. Introduction

The increasing urgency of climate change has intensified the demand for educational approaches that support not only disciplinary knowledge but also critical thinking, systems understanding, environmental responsibility, and informed decision-making. Higher education institutions have a particular role in preparing graduates to understand the interdependence of environmental, social, economic, and political systems (UNESCO, 2017; Intergovernmental Panel on Climate Change [IPCC], 2022). Recent international guidance similarly emphasises action-oriented, justice-promoting, and interdisciplinary climate education, together with the development of cognitive, socio-emotional, and behavioural learning outcomes (UNESCO, 2024).

At the same time, higher education is undergoing an extensive process of digital transformation that is reshaping teaching practices and learning environments (European Commission, 2020). Digital serious games are one group of tools that has attracted increasing pedagogical interest. By allowing learners to explore scenarios, test decisions, receive feedback, and observe consequences in simulated settings, serious games may offer meaningful ways to engage with complex real-world issues. Their value is particularly relevant to climate change education, where relationships between causes, impacts, mitigation choices, adaptation strategies, and stakeholder interests can be difficult to represent through linear instruction alone (Plass et al., 2015; Connolly et al., 2012; Tofel-Grehl et al., 2025).

Existing research suggests that well-designed game-based learning can support motivation, engagement, knowledge acquisition, and problem-solving, although outcomes vary according to game design, facilitation, learning objectives, and assessment (Plass et al., 2015; Wouters et al., 2013; Connolly et al., 2012). Reviews of sustainability-related serious games also indicate that games can facilitate the exploration of interconnected systems and collaborative decision-making, while warning that their educational value depends on how deeply they engage with the structures and leverage points underlying sustainability challenges (Foppe & von Wehrden, 2025).

Two very recent reviews further qualify these benefits. Digital games in sustainability and environmental-resilience education appear particularly valuable when systems exploration is linked to reflection, instructional scaffolding, and broader pedagogical processes; evidence

for long-term behavioural transfer remains more limited than evidence for engagement and cognitive outcomes (Paul, 2026; Xu et al., 2026).

Despite this potential, the integration of digital serious games into higher education remains uneven. Educators may hold positive views of digital innovation while lacking the pedagogical confidence, practical experience, time, resources, or institutional conditions needed to use games effectively (Ertmer & Ottenbreit-Leftwich, 2010; Redecker, 2017; Tondeur et al., 2017; Mishra & Koehler, 2006). This suggests that adoption cannot be understood only as a matter of technological access. It also requires attention to educator competence, curriculum alignment, organisational readiness, and the availability of appropriate support.

The present study was conducted within the framework of the transnational European project GAME4CHANGE. It examines the current use, adoption, and perceptions of digital serious games for climate change education in six European contexts: Poland, Portugal, Greece, Italy, Ukraine, and the Netherlands. By combining questionnaire data with focus-group insights, the study seeks to identify shared patterns and context-specific variations in educators' experiences, needs, and perceived barriers.

The study contributes in two ways. First, it provides a comparative overview of the relationship between educators' attitudes and reported practice across different higher education contexts. Second, it develops a three-gap interpretive framework—competence, familiarity, and readiness—to organise the recurring barriers identified in the combined dataset. The framework is intended as an analytical interpretation of the present findings rather than as a validated causal model.

2. Conceptual Background and Definitions

2.1 Serious games, game-based learning, and gamification

The concepts of serious games, game-based learning, and gamification are related but not interchangeable. Serious games are complete games designed primarily for purposes such as education, training, awareness, or behavioural reflection rather than entertainment alone (Michael & Chen, 2006). Game-based learning refers more broadly to the use of games or game environments to support learning. Gamification, by contrast, involves the use of selected game-design elements—such as points, challenges, progress indicators, or rewards—in contexts that are not themselves full games (Deterding et al., 2011). Maintaining these distinctions is important because each approach requires different design, facilitation, and evaluation choices.

Serious games are commonly associated with constructivist and experiential perspectives, according to which learners develop understanding through active participation, reflection, problem-solving, and engagement with meaningful contexts (Kolb, 1984; Gee, 2003). Simulated environments allow learners to test decisions and explore consequences without the costs or risks that may accompany real-world experimentation. However, the presence of a game does not in itself guarantee learning. Educational outcomes depend on the relationship between the game mechanics, the targeted learning outcomes, the surrounding instructional activities, and opportunities for reflection and debriefing (Plass et al., 2015).

2.2 Climate change education and pedagogical innovation

Climate change education is a central dimension of education for sustainable development. Its objectives extend beyond the transmission of scientific information to include critical inquiry, ethical reflection, participation, agency, and the capacity to evaluate alternative courses of action (UNESCO, 2017; Sterling, 2001; UNESCO, 2024). These aims are especially relevant

to higher education, where students are expected to analyse complexity, work across disciplinary boundaries, and connect knowledge to professional and civic decision-making.

Traditional teaching methods remain important, but they may be insufficient when used alone to represent dynamic systems, delayed consequences, uncertainty, trade-offs, and conflicting stakeholder perspectives. Digital serious games can complement lectures, seminars, case studies, and project-based learning by making selected relationships visible and by creating structured opportunities for experimentation and (Lozano et al., 2015; Squire, 2011; Tofel-Grehl et al., 2025). Their role should therefore be understood as part of an integrated pedagogical design rather than as a replacement for established teaching practices.

Recent climate- and sustainability-game scholarship also emphasises implementation conditions, including adequate preparation, curriculum fit, facilitator familiarity, meaningful learner agency, and opportunities to connect gameplay with reflection and real-world environmental problems (Fjællingsdal, 2025; Ahmadov et al., 2025).

2.3 Adoption in higher education

The adoption of digital pedagogies is influenced by interacting individual and organisational factors. Educators require technological knowledge, pedagogical knowledge, and content knowledge, together with opportunities to understand how these domains can be combined in practice (Mishra & Koehler, 2006). Beliefs, confidence, institutional culture, access to support, time, and the perceived relevance of a tool also shape whether an innovation is used consistently (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). DigCompEdu similarly treats educators' digital competence as a broad professional capacity involving resources, teaching and learning, assessment, learner empowerment, and the facilitation of learners' digital competence (Redecker, 2017).

Against this background, the present study investigates whether the limited use of serious games reflects negative perceptions of their educational value or a broader set of competence, familiarity, and institutional-readiness constraints.

2.3 Research questions

The study addresses the following research questions:

- RQ1. What attitudes do educators and relevant stakeholders report towards climate change education and the educational use of digital serious games?
- RQ2. To what extent are digital serious games currently used in the participating higher education contexts?
- RQ3. What competence-related, pedagogical, infrastructural, and institutional barriers are reported as influencing adoption?
- RQ4. What common patterns and context-specific variations emerge across the six participating countries?

3. Method

3.1 Research design

The study employed a transnational mixed-methods design integrating quantitative questionnaire data with qualitative focus-group data (Creswell & Plano Clark, 2017). The quantitative component was used to describe participants' attitudes, familiarity, reported teaching practices, and perceived barriers. The qualitative component explored how educators and stakeholders interpreted these issues, which competencies they considered necessary, and what forms of institutional or collaborative support they viewed as important. The two components were brought together through an integrated cross-country synthesis.

Data were collected in Poland, Portugal, Greece, Italy, Ukraine, and the Netherlands using a common research framework. The comparative design was intended to identify recurring transnational patterns while retaining differences associated with national, institutional, and professional contexts.

3.2 Participants and sampling

3.2.1 Questionnaire participants

The questionnaire sample consisted primarily of higher education educators and academic staff. Table 1 summarises the composition of the questionnaire sample and the characteristics reported in the partner reports.

Table 1. Profile and composition of the questionnaire sample

Country	Number of respondents	Profile and available characteristics
Poland	50	University lecturers, predominantly in the social sciences and humanities; most reported more than 10 years of teaching experience.
Portugal	43	University educators.
Greece	66	Academic staff; 54.5% reported more than 10 years of professional experience.
Italy	64	University professors and doctoral students.
Ukraine	56	Academic staff and doctoral candidates.
Netherlands	53	Academic staff and educators from higher education and adult education.

The questionnaire sample comprised 50 respondents from Poland, 43 from Portugal, 66 from Greece, 64 from Italy, 56 from Ukraine, and 53 from the Netherlands. Participants were recruited through partner institutional and professional networks using locally appropriate outreach procedures. Invitations were distributed across participating higher education contexts, with recruitment procedures adapted to the local institutional context. The study focused primarily on higher education educators, while participants with closely related educational roles were retained where their roles involved relevant teaching or educational practice.

3.2.2 Focus-group participants

Focus groups were conducted in all six participating countries with members of the project target groups and relevant stakeholders. The available composition is shown in Table 2.

Table 2. Composition and sample size of the qualitative focus groups

Country	Target group (n)	Stakeholders (n)	Total (N)
Poland	10	10	20
Portugal	10	10	20
Greece	10	12	22
Italy	10	10	20
Ukraine	10	10	20
Netherlands	10	10	20

The target-group focus groups included participants from higher education with different academic and educational roles, representing a range of disciplines and levels of experience. Participants included academic staff, educators, students, doctoral candidates, and other higher education participants, depending on the national context. Their perspectives were included to explore experiences, needs, and expectations regarding climate change education and the adoption of digital serious games and related game-based approaches.

Stakeholders included representatives of organisations, institutions, and professional networks with expertise or responsibilities related to climate change education, digital learning, educational innovation, sustainability, or related educational and professional fields. Their participation provided complementary perspectives on implementation, collaboration opportunities, and the broader conditions supporting the adoption of innovative pedagogical practices.

3.3 Data-collection instruments

3.3.1 Questionnaire

The questionnaire addressed four broad areas: (a) attitudes towards climate change education; (b) familiarity with digital games and digital serious games; (c) current teaching practices and reported use of game-based approaches; and (d) perceived barriers, support needs, and training needs. The partner-level findings were subsequently compiled for transnational comparison.

The questionnaire consisted of 14 structured items organised into five sections: (1) background information, (2) awareness of climate change education, (3) skills and competence in teaching climate change, (4) the use of digital games in teaching, and (5) future interest and support needs. The instrument included a combination of single-choice categorical questions, multiple-response questions, five-point rating-scale items, and one open-ended question for additional comments.

Five-point rating scales were used to assess participants' familiarity, perceptions, confidence, and attitudes. The response anchors were adapted to the construct being measured. Familiarity was assessed on a scale ranging from 1 = not familiar at all to 5 = very familiar. Perceived educational value of digital games was measured from 1 = not at all to 5 = to a great extent, whereas the perceived importance of integrating climate change education into university curricula ranged from 1 = not important at all to 5 = very important. Confidence-related items employed anchors from 1 = not confident at all to 5 = very confident, while technology-related comfort ranged from 1 = not comfortable at all to 5 = very comfortable.

The questionnaire also included categorical questions addressing participants' academic discipline, years of teaching experience, previous use of digital games in teaching, prior training, and willingness to participate in future professional development activities. Multiple-response items explored teaching methods currently used for climate change education, perceived barriers to adopting digital games, and the types of support considered most useful for facilitating their integration into higher education teaching.

The questionnaire was specifically developed within the framework of the GAME4CHANGE project to investigate educators' awareness, experience, confidence, and perceived needs regarding the integration of digital serious games into climate change education in higher education. The structure and content of the instrument were aligned with the project's research objectives and designed to facilitate comparable data collection across all participating countries.

3.3.2 Focus groups

The focus-group protocol explored participants' views of effective climate change education, the possible contribution of digital serious games, the skills and competencies required for their use, implementation barriers, and opportunities for professional networking and stakeholder collaboration. A common discussion framework was used across countries to support comparison.

Across the six partner implementations, focus groups followed a common semi-structured discussion guide to support cross-country comparability. Sessions lasted approximately 120 minutes, with some extending to 150 minutes where additional discussion was required.

To optimise engagement and accommodate operational constraints, delivery formats varied by country. Face-to-face sessions were conducted in Italy, Poland, Greece, and Portugal; an online session was conducted in the Netherlands via Google Meet; and a hybrid session combining in-person participation with Zoom access was conducted in Ukraine.

Each session was facilitated by at least a moderator and a rapporteur responsible for note-taking and recording management. Sessions were conducted in the relevant national language. Audio recordings, and video recordings where applicable, were made with participant consent. Partner teams prepared anonymised English-language materials using the common WP2.A1 reporting templates.

3.4 Procedure and research ethics

Each partner implemented the agreed research activities within its national context and submitted results for transnational synthesis. Participation was voluntary, and the analysis used aggregated information from the partner reports. Procedures were intended to remain sufficiently consistent to permit comparison while allowing practical adaptation to local institutional contexts.

Data collection took place across the six participating countries between April 3, 2025, and May 29, 2025. Specific data-collection dates were as follows:

- **Greece (HUA):** April 3 and May 8, 2025
- **Italy (LIM):** April 9 and May 13, 2025
- **Netherlands (ATERMON):** April 14 and April 15, 2025
- **Ukraine (TSNUK):** April 17 and April 18, 2025
- **Poland (AMU):** May 9, 2025
- **Portugal (IPLeiria):** May 29, 2025

Data handling followed consortium procedures designed to comply with the General Data Protection Regulation (GDPR) and applicable institutional requirements. Before participation, individuals received information about the research aims, voluntary participation, and recording procedures and provided informed consent. Identifying information was removed from the materials used for transnational analysis; consent records and any audio/video files were managed separately under partner data-protection procedures.

In Ukraine, data collection was adapted to wartime and security constraints through a hybrid format that combined in-person participation at the Faculty of Geography with Zoom access, enabling flexible remote participation when required.

3.5 Data analysis and mixed-methods integration

Questionnaire results were analysed descriptively using frequencies and percentages. Focus-group material was organised thematically, with attention to recurring themes and country-specific emphases. The transnational synthesis compared the quantitative and qualitative strands to identify areas of convergence, complementarity, and divergence. The competence,

familiarity, and readiness categories presented later in the paper were developed as an interpretive organisation of recurring findings across the survey results and partner focus-group summaries.

The focus-group strand was organised around three predefined areas: (a) teaching students about environmental and climate-change issues, (b) good practices for the use of digital serious games, and (c) networking with stakeholders, content authors, and higher education institutions. Where structured forms were completed during focus-group sessions, these data were distinguished from the main questionnaire dataset and used to contextualise the qualitative discussion.

Questionnaire data were summarised using descriptive statistics, including frequencies, percentages, and, where applicable, means and standard deviations for rating-scale items. Qualitative discussion data were synthesised from the focus-group reports, with attention to recurring themes, country-specific emphases, and participants' perspectives.

4. Results

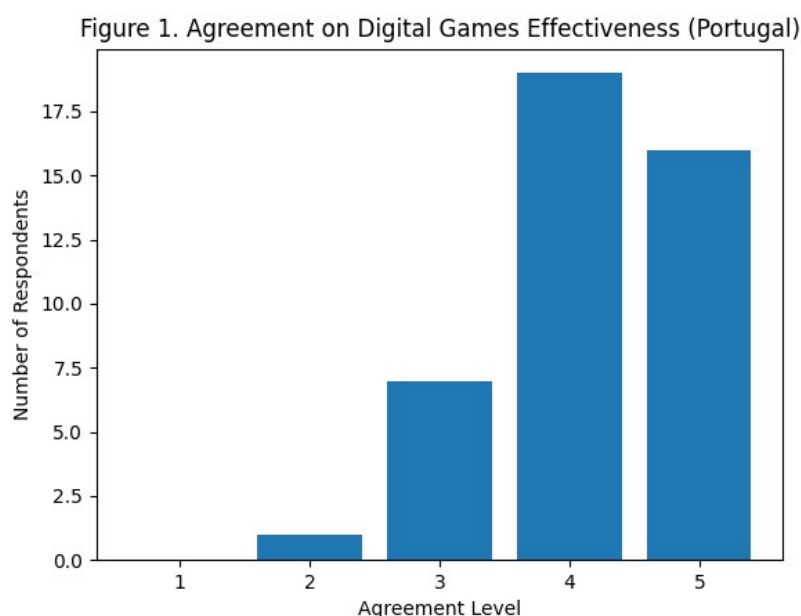
4.1 Questionnaire findings

4.1.1 General transnational pattern

Across the six participating contexts, respondents generally recognised the importance of climate change education and expressed favourable views of the potential educational value of digital serious games. At the same time, reported classroom use was limited, and established methods such as lectures, discussions, case studies, and practical activities remained more common. The findings therefore point to a discrepancy between positive perception and routine implementation rather than to widespread rejection of game-based learning.

The Portuguese data illustrate this pattern. Most respondents selected the upper points of the agreement scale when asked about the educational effectiveness of digital games, while games were reported less frequently than lectures, discussions, case studies, and other teaching methods.

Figure 1. Agreement levels regarding the educational effectiveness of digital games (Portugal)



The 5-point Likert agreement scale utilised for this item is defined as follows:

- 1 = Strongly Disagree
- 2 = Disagree
- 3 = Neutral / Neither Agree nor Disagree
- 4 = Agree
- 5 = Strongly Agree

Exact questionnaire item: "Digital serious games are an effective pedagogical tool for enhancing environmental and climate change education in higher education curricula."

Analysis of Figure 1 confirms the inclusion of all 43 Portuguese survey respondents, distributed as follows across the scale levels:

Level 1 (Strongly Disagree): $n = 0$ (0.0%)

Level 2 (Disagree): $n = 1$ (2.3%)

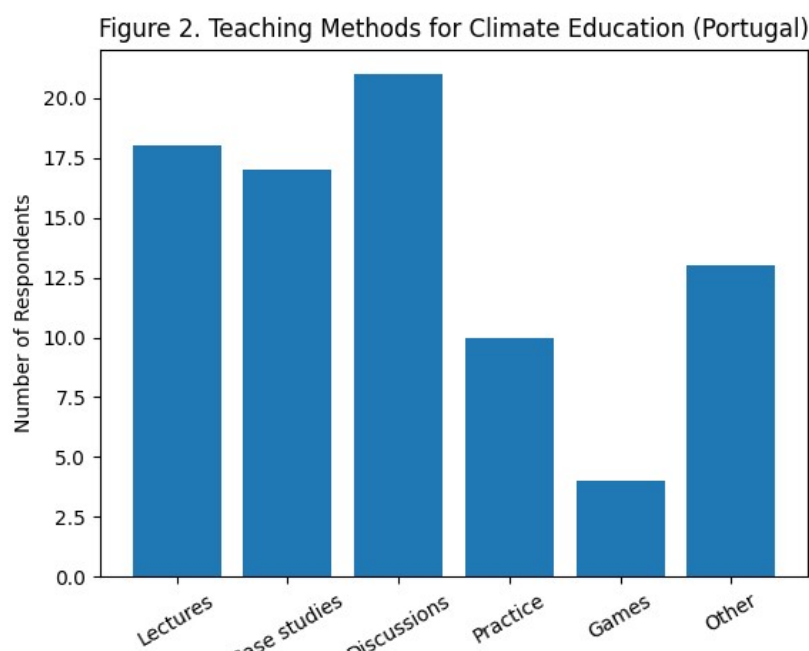
Level 3 (Neutral): $n = 7$ (16.3%)

Level 4 (Agree): $n = 19$ (44.2%)

Level 5 (Strongly Agree): $n = 16$ (37.2%)

Overall, 35 respondents (81.4%) agreed or strongly agreed; the mean score was 4.16 (SD = 0.78).

Figure 2. Teaching methods reported for climate change topics (Portugal)



Multiple responses were allowed ($n = 43$). Discussions were selected by 21 respondents (48.8%), lectures by 18 (41.9%), case studies by 17 (39.5%), "Other" by 13 (30.2%), practice by 10 (23.3%), and games by 4 (9.3%). There were 83 selections in total, corresponding to an average of 1.93 methods selected per respondent.

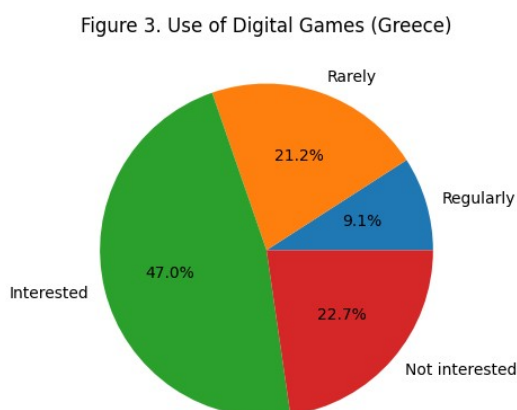
4.1.2 Country-specific patterns

In Poland, respondents reported strong support for climate change education but more moderate familiarity with digital game-based approaches. The partner findings identified limited professional training, access to suitable resources, and institutional coordination as recurring barriers.

In Portugal, educators expressed favourable attitudes towards digital serious games, but these attitudes were not reflected in routine practice. The available results indicate a marked perception–implementation gap, with conventional methods remaining predominant.

In Greece, relatively few respondents reported regular use of digital games, whereas a larger group expressed interest in future use. Familiarity ratings were concentrated towards the lower end of the reported scale, suggesting that interest may coexist with limited practical exposure.

Figure 3. Reported use of, and interest in, digital games for educational purposes (Greece)



Based on the percentages shown in Figure 3, the exact participant distribution across the categories is as follows:

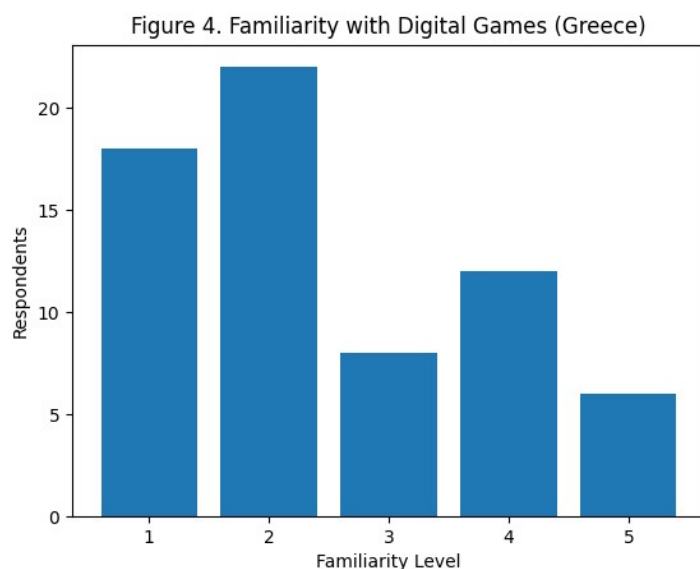
- Regularly: 9.1% → $n = 6$
 - Rarely: 21.2% → $n = 14$
 - Interested: 47.0% → $n = 31$
 - Not interested: 22.7% → $n = 15$
- Sum verification: $6 + 14 + 31 + 15 = 66$ respondents (100.0%).

Exact Survey Item:

"Which of the following options best describes your current involvement or interest regarding the use of digital serious games in your teaching/work?"

- ☐ Regularly: I currently use digital serious games on a routine basis.
- ☐ Rarely: I currently use digital serious games occasionally/infrequently.
- ☐ Interested: I do not currently use digital serious games, but I am interested in adopting them.
- ☐ Not interested: I do not currently use digital serious games and have no interest in adopting them.

Because respondents were instructed to select one mutually exclusive profile, the data points form a single categorical distribution totaling 100%, validating its representation as a single pie chart.

Figure 4. Familiarity with digital games for educational purposes (Greece)

The 5-point ordinal scale for assessing participant familiarity with digital serious games is defined as follows:

- 1** = Not familiar at all (Slight/No experience)
- 2** = Slightly familiar (Basic awareness, low personal engagement)
- 3** = Moderately familiar (Intermediate understanding/occasional use)
- 4** = Familiar (Good working knowledge/regular engagement)
- 5** = Extremely familiar (Advanced expertise/expert implementation)

Exact Questionnaire Item: "How familiar are you with the use and integration of digital serious games in educational settings?"

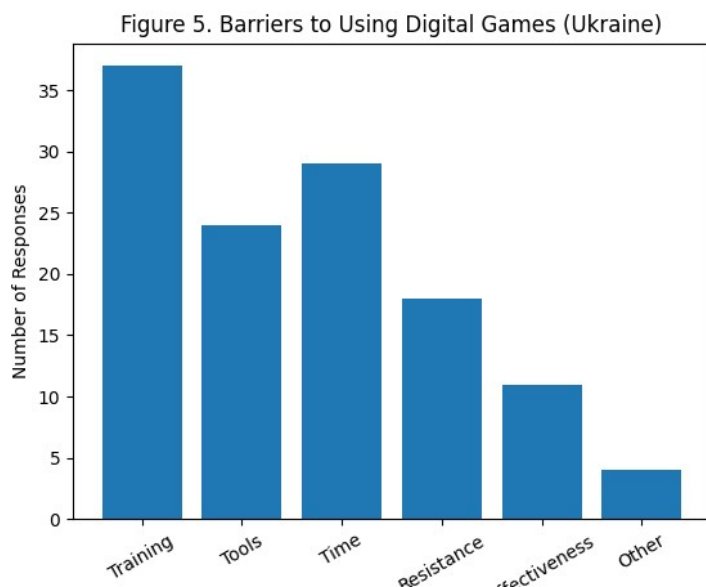
Reading the exact bar heights in Figure 4 confirms the total sample size of $n = 66$ Greek respondents, distributed as follows:

- Level 1: $n = 18$ (27.27%)
- Level 2: $n = 22$ (33.33%)
- Level 3: $n = 8$ (12.12%)
- Level 4: $n = 12$ (18.18%)
- Level 5: $n = 6$ (9.09%)

Sum verification: $18 + 22 + 8 + 12 + 6 = 66$ respondents (100.0%).

In Italy, the partner findings indicated conceptual support for climate change education and an interdisciplinary orientation. However, teaching practices were reported as predominantly lecture-based, while limited teacher training opportunities and institutional support were identified as constraints.

In Ukraine, respondents recognised the potential educational value of digital serious games, while professional training, access to appropriate tools, and time were frequently reported as barriers.

Figure 5. Barriers to using digital games in teaching (Ukraine)

The questionnaire item allowed multiple responses, with respondents able to select all applicable barriers encountered when integrating digital games into educational settings. A total of 123 selections were recorded across the 56 respondents, corresponding to an average of 2.20 barriers selected per respondent.

Lack of Training: $n = 37$ (66.1%% of respondents)

Lack of Tools/Infrastructure: $n = 24$ (42.9% of respondents)

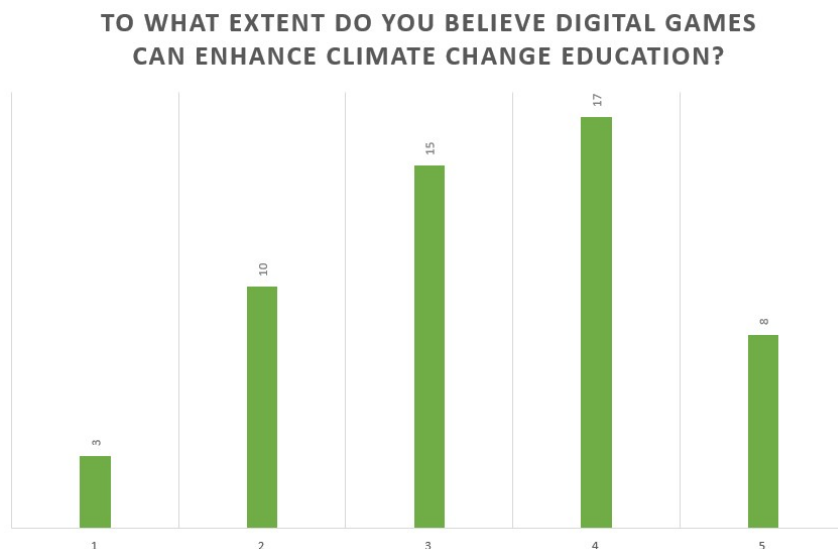
Lack of Time: $n = 29$ (51.8% of respondents)

Institutional Resistance to Change: $n = 18$ (32.1% of respondents)

Skepticism of Game Effectiveness: $n = 11$ (19.6% of respondents)

Other: $n = 4$ (7.1% of respondents)

In the Netherlands, respondents reported favourable views of climate change education and the possible contribution of digital games. Nevertheless, use remained inconsistent, supporting the interpretation that comparatively favourable technological conditions do not automatically lead to pedagogical integration.

Figure 6. Perceived contribution of digital games to climate change education (Netherlands)

The item used a five-point rating scale ranging from 1 = not at all to 5 = to a great extent.

Exact Questionnaire Item: "To what extent do you believe digital games can enhance climate change education?"

Statistical Breakdown ($n = 53$)

- Level 1: $n = 3$ (5.7%)
- Level 2: $n = 10$ (18.9%)
- Level 3: $n = 15$ (28.3%)
- Level 4: $n = 17$ (32.1%)
- Level 5: $n = 8$ (15.1%)

The mean score was 3.32 (SD = 1.12).

4.1.3 Cross-country comparison

Table 3 summarises the main shared trends and the country-specific emphases reported in the current partner analyses. The descriptions are interpretive and should not be read as statistical rankings between countries.

Table 3. Transnational patterns and country-specific emphases

Dimension/context	Summary of the reported pattern
Shared trends	Recognition of the importance of climate change education; generally favourable attitudes towards serious games; limited routine use; continued reliance on established teaching methods; recurrent demand for professional training and institutional support.
Poland	Institutional coordination and framework alignment were prominent concerns, alongside training and resource needs.
Portugal	A marked discrepancy was observed between positive perceptions and reported classroom use.
Greece	Respondents showed interest in future adoption, while familiarity and reported regular use remained limited; infrastructural and institutional constraints were also reported.
Italy	An interdisciplinary orientation was evident, but implementation was constrained by training, resource, and institutional factors.
Ukraine	Conceptual openness towards innovation coexisted with constraints related to training, time, and access to digital tools.
Netherlands	Relatively favourable technological conditions coexisted with uneven pedagogical integration.

4.2 Focus-group findings

4.2.1 General themes

Across the focus groups, participants called for more experiential, student-centred, and interdisciplinary approaches to climate change education. Digital serious games were generally viewed as potentially useful, but participants did not present them as standalone solutions. Instead, they emphasised the need to combine games with discussion, reflection, disciplinary content, and real-world application.

Four cross-cutting themes were recurrent: the need for interactive and experiential learning; the importance of interdisciplinarity and systems thinking; the value of collaboration with external stakeholders and professional networks; and the need for institutional support, training, and incentives.

4.2.2 Country-specific emphases

In Poland, participants emphasised critical thinking and interdisciplinary learning. Digital games were positioned as supportive tools that could enrich, rather than replace, established methods. Limited training and institutional coordination were prominent concerns.

In Portugal, participants highlighted simulations, experiential learning, and real-world applications. They also stressed professional networking, collaboration, and incentives as conditions for sustained pedagogical innovation.

In Greece, participants called for more structured institutional integration of digital tools and for reforms that would reduce bureaucratic obstacles and provide clearer incentives for innovative teaching.

In Italy, participants emphasised interdisciplinary sustainability education and recognised the value of project-based learning and simulations. They nevertheless described the use of serious games as constrained by structural and resource-related factors.

In Ukraine, digital games were seen as possible tools for connecting theory with practice, particularly in relation to complex societal and environmental challenges. Infrastructural, time-related, and policy constraints were reported as limiting implementation.

In the Netherlands, participants emphasised technology-enhanced learning, systems thinking, and collaboration with external stakeholders. They also highlighted the need to balance engagement with academic rigour and clearly defined learning outcomes.

4.2.3 Cross-country synthesis

The focus-group findings reinforce the questionnaire results by suggesting that educators' reservations concern implementation conditions more than the educational idea of serious games itself. Participants consistently connected successful use with clear learning objectives, appropriate facilitation, curriculum relevance, access to suitable tools, and institutional recognition. Differences between countries primarily concerned the relative prominence of infrastructure, policy, organisational culture, and professional support.

4.3 Integrated mixed-methods synthesis

The questionnaire and focus-group findings converge on a common pattern: positive or open attitudes towards digital serious games are not sufficient to produce regular pedagogical use. The focus groups add explanatory depth by showing that adoption is mediated by educators' practical capabilities, exposure to suitable examples, and the institutional conditions in which teaching takes place. The combined evidence therefore supports an interpretation organised around three interrelated gaps: competence, familiarity, and readiness.

The findings do not establish causal relationships, and the relative importance of each gap cannot be ranked on the basis of the present descriptive data. Nevertheless, the recurrence of the three dimensions across multiple partner reports provides a useful basis for structuring the discussion and for designing the next stages of the GAME4CHANGE project.

5. Discussion

The study suggests that the limited integration of digital serious games into climate change education is associated less with negative attitudes towards the tools than with the conditions required to use them effectively. Across the participating contexts, educators generally recognised the importance of climate change education and the possible contribution of interactive learning. However, reported practice remained dominated by more established methods. This finding is consistent with research showing that beliefs and interest are only part of technology adoption; competence, confidence, institutional culture, time, and support

also influence whether digital tools become embedded in teaching (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017; Mishra & Koehler, 2006).

The findings also reinforce the view that digital transformation in higher education is pedagogical and organisational, not merely technological. The Netherlands provides an especially useful illustration: relatively favourable technological conditions did not remove difficulties related to curriculum integration and pedagogical design. Access to devices or platforms is therefore necessary in some contexts but is not sufficient on its own.

Participants' emphasis on experiential, interdisciplinary, and student-centred approaches is consistent with constructivist and experiential accounts of learning (Kolb, 1984; Gee, 2003). Climate change involves complex systems, uncertain outcomes, delayed effects, and competing values. Serious games can make selected relationships available for exploration and discussion, but they require purposeful facilitation and debriefing. The game must be aligned with learning objectives and embedded in a wider sequence of preparation, play, reflection, and assessment (Plass et al., 2015; Connolly et al., 2012; Tofel-Grehl et al., 2025).

This emphasis on facilitation is reinforced by recent reviews. Large-scale syntheses identify teacher or facilitator scaffolding, reflection, curricular embedding, and implementation support as important conditions for translating game engagement into systems understanding, action competence, and more durable learning (Paul, 2026; Xu et al., 2026; Fjællingsdal, 2025; Ahmadov et al., 2025).

The results further caution against presenting serious games as universal or self-contained solutions. Games differ substantially in quality, accessibility, disciplinary relevance, technical demands, and the assumptions built into their models. Their use should be selective and critically informed. Recent reviews similarly indicate that serious games can illuminate sustainability systems and leverage points, but their transformative contribution depends on design depth and the educational context in which they are used (Foppe & von Wehrden, 2025).

Recent higher-education examples provide complementary evidence. A climate-change escape-room intervention with undergraduates reported gains in engagement and knowledge when the activities were aligned with course objectives (Carrillo-Nieves et al., 2024). A mixed-methods study of a climate-and-health serious game with medical students likewise found improvements in self-reported knowledge and selected attitudes, while also showing that affective responses such as increased climate worry require careful pedagogical attention (Stevens et al., 2024).

5.1 A three-gap interpretive framework

The integrated findings can be organised through a three-gap interpretive framework. The gaps are analytically distinct but mutually reinforcing: limited familiarity may weaken competence, while inadequate institutional readiness may prevent educators from developing or applying both familiarity and competence.

Table 4. Three-gap interpretive framework for serious-game adoption

Gap	Definition in the present study	Illustrative needs
Competence gap	Limited pedagogical and digital capacity to select, adapt, facilitate, and assess game-based learning.	Professional development; pedagogical design guidance; assessment examples; technical support.
Familiarity gap	Limited exposure to relevant serious games and limited hands-on experience of using them in teaching.	Curated repositories; demonstrations; trial sessions; peer examples; low-risk pilots.
Readiness gap	Institutional and organisational conditions that constrain sustained implementation.	Time allocation; infrastructure; access and licensing; incentives; curriculum alignment; leadership support.

The framework should be treated as a provisional analytical contribution. Further research is required to operationalise the three dimensions, test their distinctiveness, and examine whether they predict adoption across larger and more comparable samples.

5.2 Implications for GAME4CHANGE

The findings have direct implications for the design of GAME4CHANGE training, resources, and pilot activities. The project should address the three gaps in an integrated manner rather than assuming that the provision of a game or platform will be sufficient.

- Professional development should combine technical orientation with pedagogical design, curriculum alignment, facilitation, debriefing, and assessment.
- Partners should provide a curated set of accessible and discipline-relevant serious games, accompanied by concise information on learning objectives, technical requirements, duration, accessibility, and licensing.
- Pilot lessons should use low-risk, scaffolded implementation models that allow educators to observe, test, adapt, and reflect before independent use.
- Templates should help educators connect game mechanics and activities to climate-change learning outcomes, assessment criteria, and follow-up discussion.
- Inclusive design should address accessibility, different levels of digital confidence, language needs, and the participation of vulnerable or under-represented student groups.
- Communities of practice and cross-country peer exchange should be used to share lesson plans, implementation challenges, adaptations, and evidence from pilots.
- Institutional guidance should address workload, technical support, procurement or licensing, recognition of pedagogical innovation, and sustainability beyond the project period.

6. Limitations

Several limitations must be considered when interpreting the findings. First, sampling and recruitment procedures, response rates, and participant eligibility were not reported with the same level of detail across all six countries. Participant profiles also differed between contexts; for example, the Ukrainian sample included doctoral candidates, while the Dutch sample included adult-education educators. The Italy sample comprised 64 respondents and the Netherlands sample 53 respondents. These differences restrict direct country-to-country comparison.

Second, the questionnaire results are descriptive and based on self-report. Positive attitudes, intentions, and perceived barriers cannot be assumed to correspond directly to

observed teaching practice. The current data also do not measure student learning outcomes or the effectiveness of particular serious games.

Third, the questionnaire figures are not fully harmonised across countries. They visualise different constructs and response formats, Poland and Italy are not represented visually, and item-level valid sample sizes may differ from overall national samples. The transnational conclusions should therefore be understood as a synthesis of recurring patterns rather than as a statistical ranking of national systems.

Fourth, the qualitative synthesis is based on partner-level reports and common reporting templates. Unless a shared cross-national recoding of full transcripts was undertaken, the findings should not be presented as the product of a single dataset-level thematic analysis. Differences in recording, transcription, translation, and coding procedures may affect comparability. Finally, the three-gap framework is interpretive and requires further empirical validation.

7. Future Research

Future research should examine the effects of serious-game interventions longitudinally, including their influence on climate knowledge, systems thinking, critical reflection, agency, and behavioural intentions. Experimental or quasi-experimental designs could compare different forms of facilitation, debriefing, and curriculum integration rather than treating the game as an isolated intervention.

Recent reviews similarly call for research that distinguishes motivational engagement from higher-order competencies and real-world transfer, and that moves beyond short-term or predominantly self-reported outcomes (Paul, 2026; Xu et al., 2026).

There is also a need to develop and evaluate scalable implementation models for higher education. Such research should examine how games can be aligned with learning outcomes, disciplinary requirements, assessment, and blended-learning designs, as well as the costs and support structures required for sustained use.

Further studies should investigate educators' professional-development pathways and institutional conditions in greater detail. The competence, familiarity, and readiness framework could be operationalised through validated measures and tested across larger, more comparable samples. Research should also examine how the three gaps interact over time and whether interventions targeting one dimension produce changes in the others.

Finally, student perspectives and outcomes should receive greater attention. Future studies should consider motivation, accessibility, inclusion, digital confidence, disciplinary background, and the experiences of vulnerable or under-represented groups. Co-design and participatory evaluation could help ensure that serious games are both educationally meaningful and responsive to diverse learners.

8. Conclusions

This transnational mixed-methods study examined the use and perceived potential of digital serious games for climate change education across Poland, Portugal, Greece, Italy, Ukraine, and the Netherlands. Across the available questionnaire and focus-group findings, educators and stakeholders generally expressed openness towards game-based learning, while routine implementation remained limited.

The discrepancy between attitudes and practice appears to be associated with a combination of limited pedagogical and digital competence, insufficient familiarity with suitable games, and uneven institutional readiness. These dimensions are captured in a

provisional three-gap interpretive framework that can guide both future research and the design of project interventions.

Digital serious games can support experiential, interdisciplinary, and systems-oriented climate education, but their contribution depends on purposeful pedagogical integration. Effective adoption requires professional development, accessible and relevant resources, curriculum and assessment alignment, inclusive design, technical and organisational support, and opportunities for educators to learn from practice. For GAME4CHANGE, the findings support an integrated strategy that develops educators, resources, pilot models, and institutional conditions together.

References

- Ahmadov T, Karimov A, Durst S, Saarela M, Gerstlberger W, Wahl MF, Karkkainen T. (2025). A two-phase systematic literature review on the use of serious games for sustainable environmental education. "Interactive Learning Environments". 33(3):1945–1966. doi:10.1080/10494820.2024.2414429.
- Carrillo-Nieves D, Clarke-Crespo E, Cervantes-Avilés P, Cuevas-Cancino M, Vanoye-García AY. (2024). Designing learning experiences on climate change for undergraduate students of different majors. "Frontiers in Education". 9:1284593. doi:10.3389/educ.2024.1284593.
- Connolly TM, Boyle EA, MacArthur E, Hainey T, Boyle JM. (2012). A systematic literature review of empirical evidence on computer games and serious games. "Computers & Education". 59(2):661–686. doi:10.1016/j.compedu.2012.03.004.
- Creswell JW, Plano Clark VL. (2017). Designing and Conducting Mixed Methods Research. 3rd ed. Thousand Oaks, CA: SAGE.
- Deterding S, Dixon D, Khaled R, Nacke L. (2011). From game design elements to gamefulness: Defining "gamification". "Proceedings of the 15th International Academic MindTrek Conference". 9–15. doi:10.1145/2181037.2181040.
- Ertmer PA, Ottenbreit-Leftwich AT. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. "Journal of Research on Technology in Education". 42(3):255–284. doi:10.1080/15391523.2010.10782551.
- European Commission. (2020). Digital Education Action Plan 2021–2027: Resetting Education and Training for the Digital Age. Brussels: European Commission.
- Fjællingsdal KS. (2025). Expanding the green gaming horizon: A conceptual analysis of and proposed guidelines for upscaling environmental game usage in climate education. "Frontiers in Psychology". 15:1414705. doi:10.3389/fpsyg.2024.1414705.
- Foppe S, von Wehrden H. (2025). A leverage point perspective on serious games for sustainability transformation: A systematic literature review. "Sustainability Science". 20:269–286. doi:10.1007/s11625-024-01580-9.
- Gee JP. (2003). What Video Games Have to Teach Us About Learning and Literacy. New York: Palgrave Macmillan.
- Intergovernmental Panel on Climate Change (IPCC). (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.
- Kolb DA. (1984). Experiential Learning: Experience as the Source of Learning and Development. Englewood Cliffs, NJ: Prentice Hall.
- Lozano R, Ceulemans K, Scarff Seatter C. (2015). Teaching organisational change management for sustainability: Designing and delivering a course at the University of

- Leeds to better prepare future sustainability change agents. "Journal of Cleaner Production". 106:205–215. doi:10.1016/j.jclepro.2014.03.031.
- Michael DR, Chen SL. (2006). *Serious Games: Games That Educate, Train, and Inform*. Boston, MA: Thomson Course Technology.
- Mishra P, Koehler MJ. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. "Teachers College Record". 108(6):1017–1054. doi:10.1111/j.1467-9620.2006.00684.x.
- Paul J. (2026). Digital Games in Education for Sustainable Development. "Sustainability". 18(12):5930. doi:10.3390/su18125930.
- Plass JL, Homer BD, Kinzer CK. (2015). Foundations of game-based learning. "Educational Psychologist". 50(4):258–283. doi:10.1080/00461520.2015.1122533.
- Redecker C. (2017). *European Framework for the Digital Competence of Educators: DigCompEdu*. Luxembourg: Publications Office of the European Union. doi:10.2760/159770.
- Selwyn N. (2016). *Education and Technology: Key Issues and Debates*. 2nd ed. London: Bloomsbury Academic.
- Squire K. (2011). *Video Games and Learning: Teaching and Participatory Culture in the Digital Age*. New York: Teachers College Press.
- Sterling S. (2001). *Sustainable Education: Re-visioning Learning and Change*. Totnes: Green Books.
- Stevens M, Israel A, Nusselder A, Mattijssen JC, Chen F, Erasmus V, van Beeck E, Otto S. (2024). Drawing a line from CO2 emissions to health—evaluation of medical students' knowledge and attitudes towards climate change and health following a novel serious game: a mixed-methods study. "BMC Medical Education". 24:626. doi:10.1186/s12909-024-05619-4.
- Tofel-Grehl C, Hansen T, Penrod C, Ellis M. (2025). Pixels in a larger picture: A scoping review of the uses of technology for climate change education and social science. "Journal of Science Education and Technology". 34:453–473. doi:10.1007/s10956-024-10183-z.
- Tondeur J, van Braak J, Ertmer PA, Ottenbreit-Leftwich AT. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. "Educational Technology Research and Development". 65:555–575. doi:10.1007/s11423-016-9481-2.
- UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. Paris: UNESCO.
- UNESCO. (2024). *Greening Curriculum Guidance: Teaching and Learning for Climate Action*. Paris: UNESCO.
- Wouters P, van Nimwegen C, van Oostendorp H, van der Spek ED. (2013). A meta-analysis of the cognitive and motivational effects of serious games. "Journal of Educational Psychology". 105(2):249–265. doi:10.1037/a0031311.
- Xu Y, Sun Z, Zhen C, Lin Y-S, Sarker TH, Thorogood M, Lasserre P, Dulić A. (2026). From Engagement to Resilience: A Systematic Review of Game-Based Learning for Environmental Resilience. "Sustainability". 18(5):2305. doi:10.3390/su18052305.