

## Teaching Sustainability Through Play: A Literature Review Evaluating Non-Digital Board Games in Education

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# **Teaching Sustainability Through Play: A Literature Review**

## **Evaluating Non-Digital Board Games in Education**

***Abstract — Background:*** Climate change and sustainability represent global grand challenges that need widespread behavioral change. Traditional classroom methods often fail to engage learners or effectively address the psychological distance between individuals and environmental issues. Interactive strategies, especially game-based learning, have the potential to increase motivation and improve comprehension of complex sustainability concepts.

***Purpose:*** This review addresses the effectiveness of non-digital, sustainability-focused board games as educational tools for conveying climate change concepts and fostering pro-environmental attitudes.

***Scope/Method:*** This narrative literature review identifies and analyzes board games developed for environmental education. Particularly, those that include the mention of explicit sustainability or climate change themes, along with documented use in formal or informal educational settings, were required. Nineteen games, including Water Ark, Pollutaplop, Keep Cool, and CO<sub>2</sub>: Climate Policy Mod, were evaluated for their game mechanics, learning objectives, and reported educational outcomes.

***Results:*** Many of the reviewed games facilitated collaborative problem-solving, enhanced understanding of environmental systems, and reduced psychological distance from foreign concepts by immersing players in role-based scenarios. Games such as Be Blessed Taiwan and Water Ark produced measurable improvements in knowledge, empathy, and academic performance in pre- and post-game assessments. However, positive outcomes frequently required skilled facilitation and adequate classroom time for gameplay and reflection.

***Conclusions:*** Board games provide an accessible and immersive medium for sustainability education, particularly in low-resource settings. When well-designed and effectively facilitated, these games can enhance environmental literacy, increase engagement, and support sustained behavioral changes relevant to climate action and other grand challenges.

***Keywords — Sustainability Education, Environmental Literacy, Behavioral Change, Focus Groups***

## **I. Introduction**

Climate change and sustainability are complex topics that will require people to adjust their day-to-day behaviors to mitigate global effects [1]. Education is a necessary component of fighting climate change, but traditional teaching and learning methods are often not effective when it comes to climate change and sustainability [2]. Students often struggle to effectively learn new material in a complex form. Many topics are brand new to students, and thus, they may display psychological distance from the topics being taught, meaning they struggle to make connections and truly digest new information [3]. This is especially true for global grand challenges faced in locations not directly in student's communities. The lack of direct

experience with grand challenges impedes the individual from empathizing with and internalizing the knowledge they would learn from the material, causing a true understanding of these circumstances to be ignored. One potential solution is the use of board games, which can be highly innovative tools when breaking down complex environmental issues to be more palatable and initiating a closer tie to the problem [4].

Implementing effective teaching methods in the classroom (and beyond) enables students to break down complex concepts more effectively and can enhance students' comprehension [5]. Tapping into the motivations of the students, whether intrinsic or extrinsic, can further motivate their learning. Intrinsic motivation comes from recognizing the personal desire for growth, and extrinsic motivation comes from recognizing the attractiveness of rewards or the deterrence of punishments that incite action in an individual. Creating environments where students can tap into their motivations is crucial for an individual to further learn. To supplement the common lecturing methods that teachers utilize in academic settings, we propose that they implement methods of game play, specifically board game play, to engage students in real-world problems and have them build towards a goal while also deepening their level of knowledge.

One area where issues of sustainability are enumerated is the UN Sustainable Development Goals (SDGs), comprising 17 goals that humanity must address to secure a sustainable future and promote positive change in the human condition [1]. In this paper, we will review many board games that have been designed to promote the SDGs (and sustainability in general) that are often used in educational environments. Targeting games highlighting SDGs shows the progression of education in areas that have already been identified as challenging to learn. Furthermore, we will explore the differences between video games and physical board games, discussing why board games can be an effective tool for education, especially with children and those in low-resource environments. Challenges involved with designing and implementing board games are crucial to note, along with considerations for those interested in creating their own sustainability-focused board game. Board game designers, educators, non-profit organizations, and government officials interested in sustainability education are the primary audience for this paper. Of these groups, those focused on primary and secondary education would be the most engaged, as they would be directly affected by the implementation of these teaching practices.

## II. Methods

### *A. Databases Searched*

Utilizing academic article databases, we found around 40 relevant sources through a keyword search. This keyword search utilized AI-powered research tools such as Keenious and Consensus to identify high-quality and relevant sources of targeted educational board game content. Keywords used include “board game”, “sustainability”, “education”, “climate change”, “tabletop”, “gameplay”, and “game-based learning”. A synopsis of each article was made to determine if they aligned with the topics of this Literature Review. Collected together, an annotated bibliography was produced of 19 sources, detailing the goals and objectives that were discussed in commonality between them. Several common themes were identified as being relevant for this literature review: “Why games”, “Issue Addressed”, “What games can do”, “Challenges for Implementation”, “Types of games”, “Considerations for design”, and

“Sustainable Development Goals”, along with examples of relevant board games. Each topic was chosen to be a key element of what makes a game an immersive and beneficial experience when utilized as a learning tool in educational settings.

### *B. Research questions*

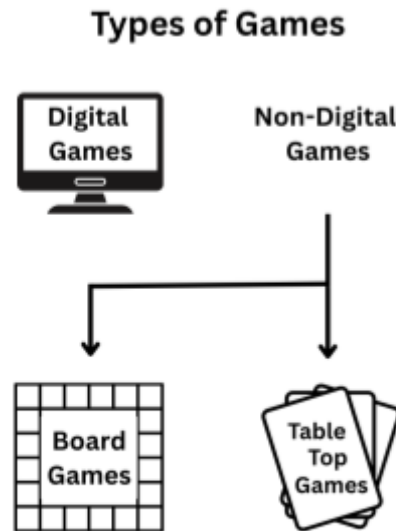
When narrowing our search for critically and effectively applied board games for sustainability education, we asked if the articles found could answer the question: “How can board games be used to educate students about the Sustainable Development Goals?” These 17 goals highlight impactful and complex humanitarian and environmental issues in the world. Understanding the potential of a tool like board games to help students understand them can enable educators, policymakers, and designers in their efforts to transform communities. Conclusions of the following were identified from the games used or created for this purpose: a) Who developed the board game? b) Why was it developed? c) What are the issues and concerns they are trying to address? d) How was it implemented? e) What were the results and feedback?

### III. Types of Games

There are many different ways that game play can be implemented in education. In this section, we discuss several types or categories of games. At the highest level, we have Digital Games and Non-Digital Games (Figure 1). Digital games are games played on technological devices, while non-digital games are games played without electronic devices. Both encourage the player to be engaged in the topic and the learning process.

Non-digital games, which can also be referred to as analog games, can be categorized into board games and tabletop games. Board games involve a specialized surface, rules, tokens, and interaction between multiple players [6], while tabletop games are games played on a table, not excluding board games but additionally including games played with cards and other methods. This physical interaction between users enables a discussion not only in gameplay, but also in the topic at hand being presented and collaboration towards a common goal. In this paper, we will be primarily focused on non-digital games and specifically board games. These analog games have the advantage of being more accessible in low-resource environments, as they do not require access to electronic devices.

Several types of gameplay can be encouraged by board games. One way of gameplay is competitive, with players making decisions in competition with other players and for their advancement in gameplay. This conflict or competition between players may cause players to make selfish decisions that, in turn, may benefit or hurt their game status. On the other hand, Cooperative game play involves collaboration between players and building towards a common goal through communication, which many real-world issues addressed in education require [7]. For cooperation to be maximally beneficial for players, a form of deep play must be involved [8]. Deep play can be defined as gameplay where there are high stakes involved and an overarching goal to be reached by players. This goal helps players orient their actions and measure their progress within the game. Many successful games integrate both cooperative game play and deep play.



*Figure 1: Types of Games*

These methods of gameplay, however, can only be supported in educational settings through games that are “serious games”. This term refers to a game, while targeting enjoyment in some aspect, it has a primary focus on education or developing a deeper understanding of a topic [8]. With the ability to imitate real-world problems, games allow for a safe space to address issues that otherwise would be taught in a non-immersive manner, such as a lecture. This enables the gamification of learning and education, which is the transformation of topics and ideas into a game setting. Games can change the perception that students have of learning new material, especially about topics and problems currently faced in the world. Cooperative, serious games that involve deep play lend themselves to the topic of sustainability education and the Sustainable Development Goals.

#### IV. The Educational Benefits of Board Games

The physical aspect of board games in education presents one of their most beneficial aspects: the immersive experience that students can experience when engaging in the game. This allows for a shift in their current reality and perspective on the problem proposed to them. Games prompt players to take part in a role that they might not otherwise be able to experience. For example, in a game called “Cheap Nature”, players create a city, manage resources, and face real-world sustainability challenges [5], placing the players in the role of important community decision-makers. Players visually and quickly see changing results from their actions, seeing the possible impact that they could have in real-world scenarios. This proved to be an effective learning tool for cognitive and communication skills and topics [9].

It is also critical to understand that real-world problems require not only learning and conceptual understanding, but also personal connection. The immersion of gameplay allows for this link between the problem and the individual to be made. What makes this possible are the key aspects of the act of play: it is a voluntary act that includes intrinsic motivation, active engagement, and make-believe qualities [10]. Each player must have a voluntary self-motivation to engage in gameplay. They must have intrinsic motivation, or the push for someone to do

something because they enjoy it. Through active engagement, players take a direct part in the game being played. Finally, the make-believe quality of games creates an environment for creativity and fun that can enhance learning in a classroom setting that often lacks those characteristics. Games can push players to take further action and tackle real-world problems that are presented in these games [3]. Players can gain a new perspective that can help break the psychological distance from complex topics through the immersive experience of gameplay.

Immersing players within a game opens the possibility of adapting a new persona or even challenging their current perspectives. Enabling expression within the individual, gameplay can also bridge a gap of communication between players themselves and with individuals outside the game, such as instructors or even policy makers [11]. Games can strengthen the ability for collaboration not only between individuals at play, but also for disciplines of study that in outside scenarios would not be possible [12].

Beyond enhancing communication, board games can also help to break down complex concepts and increase players' understanding of them. Encouraging serious game playing can additionally allow for an informal and more comfortable setting for educational dialogue to take place. Game mechanics, the foundation of how games work, including rules and procedures, have a large influence on how dialogues about complex topics unfold. These board games act as "micro-level environmental simulators" that further the immersive experience [12].

With the immersion through gameplay and further topic comprehension, completion of gameplay and board games can be an effective learning method. This new process of learning can also promote new and innovative ways of thinking. In a simulated setting, ethical thinking and decision-making are made possible, placing one into the game [5]. As thought is deepened, strong inquiry brings to the surface possible educational or systematic problems that require resolution. This can be implemented towards the real-world problems addressed, such as environmental issues. Furthermore, it socially and intellectually engages the student [11]. Placed into the educational environment, it poses as a new teaching method for many classrooms. While challenging the players, the implementation of board games utilizes these active learning components to motivate learning and engagement.

## V. Examples of Sustainability-focused Board Games

We have collected 19 relevant games that address sustainability and the SDGs and show how board games can teach players about real-world problems. It is important to note that many of these games were created to be implemented in an educational setting, while some were sourced through the mainstream market. The games analyzed were Pollutaplop, Paved Paradise, My Eco Town, Sui-Maru, Bewust Milieu, The Settlers of Catan: Oil Springs, Evolution: Climate, Global Warming, Keep Cool, CO2: Climate Policy Mod, Be Blessed Taiwan, Water Ark, and more.

### A. *Pollutaplop*

Pollutaplop, a game addressing pollution of natural environments, was developed by teenagers to determine if designing board games would increase a youth's knowledge of environmental issues. The game's development engaged the adolescents through a method of systems thinking whereby understanding of the Earth's functions is studied holistically and through relationships rather than divided into parts. Consequently, gaps in knowledge were

identified and filled, difficulties in representing complex phenomena accurately were realized, and an understanding of the interconnected nature of environmental relationships/issues was achieved. How educational learning gaps were filled through gameplay was how success was measured for the creators. [12]

#### *B. Paved Paradise*

Paved Paradise, developed and trademarked by a PhD student from Prescott College, urges players to create sustainable communities to question what is acceptable in human societies when it comes to urban development. The game addresses preservation, zoning laws, budgeting, natural disasters, urban sprawl, carbon footprint, equity, energy systems, waste and water management, and construction. By playing this board game, the focus group recognized the importance of water and green infrastructure. Moreover, environmental statistics were presented on one face of the game cards, and the players realized that the design of an environmentally friendly community is multifaceted. This game, as part of a dissertation, is copyrighted and may be used under licensing. [13]

#### *C. My Eco Town*

My Eco Town, a board game addressing waste management, was modeled and prototyped after various game design methods were studied by the authors. Players collect garbage cards in a town setting that are to be dispensed at scattered manufacturing locations for puzzle pieces, which are assembled to win. The focus group, children aged seven to twelve, was able to comprehend the value of waste materials given their price tag for recycling and the requirement of disposal at the appropriate manufacturing facility. [14]

#### *D. Sui-Maru*

The board game Sui-Maru was developed in collaboration with scientists, administrative officers, civic groups, and students from Japan's coral reef islands. It is meant to inform people on the effectiveness of proper water conservation and to create an opportunity to discuss water issues. In essence, players hold different occupations whose roles are closely tied to water usage, the water cycle, and consumption on the island. Topics discussed through the board game include saltwater intrusion, cooperation, depletion, profit-making, and supply and demand. Tests on the board game's effectiveness were conducted on fifth-grade students from Tarama Island. Reports collected after gameplay revealed an understanding of limiting water use, avoiding saltwater intrusion, discussing actions with others, and the political role of water management. [7]

#### *E. Bewust Milieu*

Using a systematic instructional development model, a Dutch master's student designed a board game called Bewust Milieu targeting climate change education, specifically sustainability and the environment. Bewust Milieu is a discussion-based board game with cards that pose stimulating questions, and where points are accumulated based on correctness. In focus group interviews conducted at the end of gameplay, the seventh and eighth graders disclosed they learned about recyclability, consumption habits, and water management. [15]

#### *F. The Settlers of Catan: Oil Springs*

The Settlers of Catan: Oil Springs was developed by environmental educators in collaboration with the Catan publishers to raise awareness about oil use and its environmental

impacts regarding human development and natural resource management. Oil Springs is a scenario extension of the well-known Settlers of Catan board game, where expanding settlements can grow faster and reach victory sooner with oil. Unfortunately, a side effect of this valuable resource is environmental damage and climate devastation, which could culminate in the defeat of all players should it be abused. [4]

#### *G. Evolution: Climate*

Evolution: Climate is an expansion pack for the game Evolution, published by North Star Games, that addresses climate change effects. Players design species at each round with the goal of adapting and evolving them to the extreme climate determined by limited resources and feeding habits. This includes diet and biological traits; the expansion pack also introduces un-adaptable climate changes. The game thus highlights the link between a player's actions and their impact, working as an environmental simulator. [4]

#### *H. Global Warming*

Global Warming is a strategic card-based game about commodities manufacturing and how they influence ecological systems. Players must collect happiness points by providing public goods. These industries produce pollution that is tracked individually and collectively. A third scale tracks warming, at which negative effects occur after certain points are reached. [4]

#### *I. Keep Cool*

Developed at the Potsdam Institute for Climate Impact Research (PIK), Keep Cool is a political negotiation game where each player takes the role of a country to pursue economic objectives. However, greenhouse gases are released by these actions, so each round, the player must decide whether to implement environmental initiatives or continue the individual path. As such, cooperation is essential, or the risk of global catastrophe runs high. [4]

#### *J. CO2: Climate Policy Mod*

The board game CO2, in a case study determining the potential of game modification for educational purposes, was altered to improve global warming policy accuracy. The mod added carbon tax, carbon emissions permits, an economic incentive component, and clean energy investment opportunities to a game where participants play as power companies. Players focus their attention on the policy-makers' problem of aligning the incentives of power companies to reduce carbon dioxide output. Players will learn how policies that support research and/or keep energy cheap work and the way they change the incentives of power companies. The impact of policy on global climate conditions is directly observable by players. [16]

#### *K. Be Blessed Taiwan*

As a board game that simulates Taiwan's economic development process, Be Blessed Taiwan was developed for sustainable development education. Players work to achieve a balance between economic development and biological conservation while maintaining people's way of life in Taiwan. The tradeoffs involved with these issues push players to experience both confrontation and opportunities for collaboration. [8]

#### *L. Water Ark*

Developed by a research team from Taiwan, Water Ark sees players focus on water

resource responsibility and public benefits from such. The gameplay is situation-based and has players roleplay the government, the agricultural sector, industry, and the public. Through this roleplay, players learn how to prioritize the public benefit, be responsible with resources, and how to improve decision-making. The interplay between the different roles and other game resources improves players' ability to comprehend holistic systems, negotiate and plan together, and ultimately take more responsibility for environmental resources. [8]

#### *M. Mystery of Motion*

This game was developed by a team of researchers from the Faculty of Physics, Hanoi National University of Education, and the Department of Science Education, National Taipei University of Education. The board game aims to address concerns in STEM education by increasing student engagement, improving cognitive learning outcomes, and providing an alternative, interactive instructional format to support STEM education. It was designed for three or more players to explore fundamental concepts of kinematics with practice activities. The game sessions were conducted in class. Pre and post-tests measured cognitive gains, and surveys measured students' motivation and engagement. [17]

#### *N. BLUTUBE: Who brings the water home*

Developed by researchers in collaboration with the municipal education office of the city of Lucca, Italy, this board game aims to address concerns related to sustainable water usage and environmental education. This had a positive impact on the students' self-reported awareness and behavior regarding water consumption, which was still measurable six months after the end of the activity. The implementation of this board game helped reduce water waste, foster a more responsible mindset regarding water as a shared resource, and build a foundation for lifelong pro-environmental habits. [18]

#### *O. Companion: An Agroecological Adventure*

The board game was developed by researchers and the University of South Florida as a teaching tool for agroecology in educational settings. The game involves small groups of 2 or 3 students designing and managing a small garden bed, selecting plants, and facing stochastic events like pests, weather, and seed shortages. Players receive points for beneficial arrangements such as cinnamon planting, pest deterrence, pollinator-friendly plants, and ground cover. The result shows that the game helped them visualize how agroecosystems between crop productivity, biodiversity, synergies, recycling, efficiency, resilience, human and social values, culture and tradition, governance, and circular economy interact. [19]

#### *P. Make it Green*

This board game was developed as a tool to raise climate change literacy and awareness among younger students by making them encounter situations and decisions related to climate change, renewable and non-renewable resources, sustainability, and the environment, rather than memorizing facts. They conducted a pre-test before playing the game, then students played out scenarios of climate change solutions, and lastly, a post-test to evaluate knowledge and awareness changes. The emphasis on solutions for climate change rather than facts means students were not simply learning about problems, but actively thinking about what they and the community can do to help. [20]

#### *Q. Spaceship Earth*

This game was developed to raise knowledge on waste, resource reuse, circular

economy, material flow, and environmental impact, and was presented at the Global Conference on Sustainable Manufacturing (GCSM) 2023. They emphasize Buckminster Fuller's "Spaceship Earth" metaphor, where Earth is a closed system whose resources must be managed thoughtfully. The board game involves four players assuming the role of crew members on the spaceship. Each has its specialties and needs to work together to produce, recycle, upgrade components, and machinery under constraints of material waste, energy consumption, and air quality. A pre- and post-game survey was conducted, showing that the board game enabled increased understanding of the 6 R's: Rethink, Refuse, Reduce, Reuse, Repair, and Recycle, of sustainable manufacturing. [21]

#### *R. Snakes and Ladders*

This modified version of the classic "Snakes and Ladders" was developed by Wulanyani (researchers from Udayana University, Indonesia, and Asahikawa Medical University, Japan) to address the high prevalence of Taeniasis (tapeworm infection) in Bali, Indonesia. This tool was made to improve the knowledge of health among elementary school children about the life cycles of tapeworm variants and proper hygiene and sanitation practices. Using a familiar game, the "ladders" represented positive behaviors advancing the players, while "snakes" represented risky behaviors moving players backwards. Implemented through a quantitative study, students were divided into a play group and a control group that received traditional lectures. The results showed the game was effective, with increased knowledge about preventing the topic compared to the lecture-only group. [27]

#### *S. Dengue Prevention Board Game*

This educational board game was developed at the Universitas Muhammadiyah Purwokerto and Universitas Indonesia to address the critical public health issue of Dengue Hemorrhagic Fever (DHF) in Indonesia. Designed for school-aged children, it aims to change attitudes toward DHF prevention to an active commitment. Tackling the lack of engagement using playful engagement to teach prevention strategies. With a quasi-experimental design, students were split into a play group and a control group. The game required students to answer questions and perform tasks to eliminate mosquito breeding grounds, allowing them to progress. A significant increase in positive attitudes towards prevention among the students who played was proven. [23]

*Table 1: Overview of board games in reviewed studies*

| <i>Game Title</i>                            | <i>Origin &amp; Selection Rationale</i>                                          | <i>Availability</i>     | <i>Critique Methods &amp; Validation</i>                                                             | <i>Assessment Strategy</i>                                                  | <i>Educational Topic</i>                            |
|----------------------------------------------|----------------------------------------------------------------------------------|-------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------|
| <b>A. Pollutaplop</b>                        | Student project; created as a learning process.                                  | No (Student prototype)  | Qualitative teacher observation of game mechanics; no formal testing on students.                    | No formal pre/post (assessment was the creation process).                   | Biomagnification of pollutants in marine ecosystems |
| <b>B. Paved Paradise</b>                     | Developed by authors (researchers from Brazil).                                  | No (Prototype)          | 42 participants (students/experts); questionnaires and video analysis; expert validation of realism. | Yes; pre-test presentation with questionnaire; "Structured Research Cycle". | Product-Service Systems (PSS) and sustainability    |
| <b>C. My Eco Town</b>                        | Designed by authors for the study.                                               | No (Research prototype) | 132 students (ages 8-10); combined questions with direct observation (self-reporting).               | Yes; pre/post questionnaires on behavior and attitude.                      | Plastic pollution (Primary school level)            |
| <b>D. Sui-Maru</b>                           | Designed by authors to visualize invisible groundwater on Tarama Island.         | No                      | 42 students; mixed methods (Likert scale + text mining of comments); tailored to local geography.    | Yes; pre/post comprehension questionnaires.                                 | Invisible groundwater cycle                         |
| <b>E. Bewust Milieu</b>                      | Master's thesis project; identified curriculum gap for 7th/8th graders.          | No                      | Interviews with teachers, student questionnaires, and observation.                                   | Yes; pre/post teacher interviews and student questionnaires.                | Active Learning strategies                          |
| <b>F. The Settlers of Catan: Oil Springs</b> | Commercial game; chosen to analyze complex environmental systems.                | Yes                     | 17 participants (Qualitative Thematic Analysis); assessed engagement, not retention.                 | Post-gameplay interviews only.                                              | Environmental systems                               |
| <b>G. Evolution: Climate</b>                 | <i>See F (Commercial game)</i>                                                   | Yes                     | <i>See F (Qualitative focus groups)</i>                                                              | Post-gameplay interviews only.                                              | Environmental systems                               |
| <b>H. Global Warming</b>                     | <i>See F (Commercial game)</i>                                                   | Yes                     | <i>See F (Qualitative focus groups)</i>                                                              | Post-gameplay interviews only.                                              | Environmental systems                               |
| <b>I. Keep Cool</b>                          | <i>See F (Commercial game)</i>                                                   | Yes                     | <i>See F (Qualitative focus groups)</i>                                                              | Post-gameplay interviews only.                                              | Environmental systems                               |
| <b>J. CO2: Climate Policy Mod</b>            | Modification of commercial game CO2; modded to simulate specific policy options. | Base game: Yes; Mod: No | Case study in design; theoretical argument validating the model's accuracy.                          | No.                                                                         | Specific policy options in the energy market        |

| <i>Game Title</i>                                | <i>Origin &amp; Selection Rationale</i>                                    | <i>Availability</i>                  | <i>Critique Methods &amp; Validation</i>                                                                     | <i>Assessment Strategy</i>                                      | <i>Educational Topic</i>                                    |
|--------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-------------------------------------------------------------|
| <b>K. Be Blessed Taiwan</b>                      | Commercial game (Taiwan); aligns with sustainability pillars.              | Yes                                  | University students; mixed-methods (test scores + interviews); significant improvement in SDG understanding. | Yes; pre/post knowledge and attitude assessments.               | Socio-economic history                                      |
| <b>L. Water Ark</b>                              | Commercial game (Taiwan); aligns with sustainability pillars.              | Yes                                  | University students; mixed-methods (test scores + interviews); significant improvement in SDG understanding. | Yes; pre/post knowledge and attitude assessments.               | Environmental constraints                                   |
| <b>M. Mystery of Motion</b>                      | Developed by authors using the EPDPE process to transform learning styles. | No (Prototype)                       | Mixed-method with 52 high schoolers; multiple choice/surveys; no control group.                              | Yes; pre/post tests.                                            | Physics/STEM topics                                         |
| <b>N. BLUTUBE: Who brings the water home</b>     | Created by Municipality of Lucca, Italy for grades 2-4.                    | No (Custom educational tool)         | Quasi-experimental (2,000 students, treatment vs. control); measured long-term effects (6 months later).     | Yes; pre/post tests/surveys + 6-month follow-up.                | Water cycle and municipal water system                      |
| <b>O. Companion: An Agroecological Adventure</b> | Developed by researchers (Das et al.) to teach through play.               | Free "Print-and-Play" (Downloadable) | Tested with 50 undergrads; qualitative analysis (open-ended surveys & observation).                          | No formal pre/post; relied on qualitative feedback/observation. | Companion planting & agroecological principles              |
| <b>P. Make it Green</b>                          | Created by researchers (ADDIE model); addressed lack of topic awareness.   | No (Research prototype)              | Descriptive Developmental Research (70 grade 7 students); expert content validation; no control group.       | Yes; pre/post knowledge tests.                                  | Renewable energy and sustainability                         |
| <b>Q. Spaceship Earth</b>                        | Developed at TU Berlin to address teaching complex concepts.               | No (Prototype)                       | Mixed-methods; pre/post surveying and "debriefing"; demonstrated better understanding.                       | Yes; pre/post questionnaires.                                   | Trade-offs inherent in manufacturing                        |
| <b>R. Snakes and Ladders (Tapeworm Mod)</b>      | Modified classic game to teach specific biology topics.                    | Base game: Yes; Mod: No              | Quantitative experimental design (167 students); comparison against control group (lecture).                 | Yes; pre/post knowledge scoring.                                | <i>Taenia solium</i> and <i>Taenia saginata</i> (tapeworms) |
| <b>S. Dengue Prevention Board Game</b>           | Developed by researchers; play identified as crucial for age 10-12.        | No (Prototype)                       | Quasi-experimental with control group (92 participants); scored attitude changes.                            | Yes; pre/post questionnaires (gameplay vs. lecture).            | Dengue prevention (mosquito control)                        |

## VI. Evaluating the Effectiveness of Environmentally-focused Board Games

Beyond being able to alter the environments in which they are placed, board games can have additional outcomes that have been analyzed and studied. Research about many of these games measured learning outcomes and enjoyment factors of their players [24]. The successful implementation and positive learning outcomes highlight the potential of educational board game play.

For the game Water Ark, success was measured using four goals, including the cross-orientation system knowledge (COSK), responsibility of water resource environment (RWRE), value of public benefits (VPB), and empathy and negotiating thinking (EaNT) [9]. Testing these goals was done using open-ended questions, interviews, and questionnaires, where players could display their knowledge and provide the information needed to determine the players' comprehension of the various goals. Other studies showed that after playing board games, players developed a deeper understanding of the topics, especially environmental issues, and were able to better understand connections between societal and technological impacts [5]. Building understanding of complex topics is the first of many small steps towards education and creating change in the real world. Without high-tech requirements of implementation, the use of board game play can be done in environments where both a connection to the issues addressed can be empathized with or otherwise, allowing for a diverse range of settings [13].

A comparison of four commercially available environment-themed board games to gauge their effect on environmental awareness showed that board games simplify supposedly complex environmental phenomena that more effectively resonated with the respondents [4]. Moreover, playing these board games provided the respondents with the opportunity to experiment and experience how their actions affect the environment because of the board game's physical representations and the players' active participation. Unfortunately, the design of these particular board games sometimes undermined cooperative and sustainable sentiments because polluting technologies were cheapest and advanced the probability of victory, and supported the harming of other players for personal victory.

SDG issues of concern are, however, not the only thing that can be taught through gameplay. For example, critical thinking skills, verbal skills, financial principles, and more can be learned through gameplay. Behaviors can change due to the increase in perspective and reduction of psychological distance from complex topics. Preconceived ideas can even be altered and expanded within an individual [1]. These shifts and expansions of ideas and ways of thinking can be exchanged between players and, in turn, built upon [8]. In the event that knowledge is increased from game play, an increase in academic performance can also be shown [25]. Statistical tests showed a positive correlation between increased academic performance and game play, in comparison to a "normal classroom experience". In the gameplay of Be Blessed Taiwan, it was recorded that there were significant increases in performance from the findings of pre-test and post-test evaluations [8].

Together, these studies show that board games can be an effective educational tool that can help learners grasp complex concepts, increase their understanding, build skills, and ultimately change their behaviors. But implementation of board games in the classroom does not

come without challenges.

## VII. Challenges with Implementing Board Games in the Classroom

When it comes to implementing games in the classroom, a facilitator must have a level of knowledge of the game and its topical themes to properly run the game. This could pose a challenge if the topic or the gameplay itself is outside of their expertise. To ensure that the instructor holds complete knowledge of game play, they likely need to learn to play the game themselves. They also must learn and understand the full complexity of the issue addressed, along with the skill to measure the understanding after learners engage with the game [11]. Ultimately, if the game is not facilitated properly, it will not provide an in-depth understanding of the issue being addressed.

The instruction must also provide the essential materials and resources to facilitate the gameplay. While high-tech technology would not be required, if items such as the board game, cards, and other key items are missing, full immersion in gameplay is not possible [13]. Additionally, due to the current state of innovative technology, the physical use of gameplay can be both resisted by instructors and players [5]. The time commitment that the postgame tests require, along with the gameplay, may deter classrooms from implementing and evaluating gameplay. Effective learning through gameplay is often more effective with a skilled facilitator. In one study, it was shown that the use of gameplay for education without teachers present was less effective than in comparison to lecture-based learning [1]. The time to play games in the classroom can also pose an obstacle with busy school schedules and lots of content to cover already. But if implemented into the curriculum ahead of time, board game play can be done with allotted time for other lessons.

## VII. Considerations for Designing Environmentally-focused Games

Designing effective games for education is key to their implementation. Well-designed games were found to enrich the foundation that would deliver lessons and ideas to the players effectively. One common game design method is the ADDIE method, which requires five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE method was crucial to building a foundation for the instructional development of games [1]. Another approach, called the Game Development Life Cycle (GDLC), involves six phases: Initiation, Pre-Production, Testing, Beta, and Release. Used to develop an educational game that, as a result, found 71.1% of their players gained environmental knowledge; its implementations into design have proven effective [26]. These methods, resembling scientific models of sorts, require structure and refinement. Most essentially, the three main principles of game design, game mechanics, dynamics, and aesthetics must be [13]. Additionally, for an immersive and, in turn, responsive experience for players to engage, the game must not be too overly complicated to execute, and most involve realistic components for players to be able to place themselves into the environment [3].

## IX. Conclusion

Games can be a fun, engaging, and importantly, effective way to educate students about complex topics. Board games are promising for adding game play to classrooms, especially in low-resource environments that may not have access to the technology needed for video games. Environmental and sustainability-related topics, especially the Sustainable

Development Goals, can be effectively learned through gameplay. In this paper, we reviewed 19 examples of sustainability-related board games that can be taken as inspiration for board game designers, educators, non-profit organizations, and more as they seek to educate younger generations on the importance of sustainable behavior. Combating and mitigating climate change will need people around the world to change their behaviors, and board games are a promising avenue to encourage this change in students around the world. Diving further into studies on this topic should measure the long-term behavioral impact of this information, as well as the retention of it after playing the board games created. Additionally, the creation of these games, specifically the optimization of the mechanics for varying age groups and audiences, maximizes the usage of these games for their primary purpose of education.

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