sustainability

MDPI

Article

Applying Game-Based Experiential Learning to Comprehensive Sustainable Development-Based Education

Shin-Jia Ho [1], Yu-Shan Hsu [2], Chien-Hung Lai [2], Fong-Han Chen [3,*] and Ming-Hour Yang [2,*]

[1] Department of Center for General Education, National Taichung University of Science and Technology, North District, Taichung City 406053, Taiwan; shinjia@nutc.edu.tw
[2] Department of Information and Computer Engineering, Chung Yuan Christian University, Chung-Li District, Taoyuan City 320314, Taiwan; b9111029@gmail.com (Y.-S.H.); soulwind@cycu.org.tw (C.-H.L.)
[3] Department of Environmental Education, National Taiwan Normal University, Taipei City 106209, Taiwan
* Correspondence: ddmhan@gmail.com (F.-H.C.); mhyang@cycu.edu.tw (M.-H.Y.)

Abstract: To promote the United Nations' Sustainable Development Goals (SDGs), public awareness of the importance and urgency of sustainable development should be raised by providing relevant education programs. Although game-based learning has been confirmed to be one of the most effective routes to deepen public understanding of the SDGs and sustainable development in general, games for comprehensive sustainable development-based courses have yet to be popularized. Thus, we developed a game-based learning approach that delivers comprehensive conceptual information on SDGs. Based on Kolb's theory of experiential learning, students understood the relevance of the SDGs by playing a board game designed to simulate the real world, including national and international policies. Furthermore, considering the suspension of in-person learning and shifts to digital instruction caused by the ongoing COVID-19 pandemic, a digital version of the board game was created to compare the effects of digital and non-digital game-based learning. A comprehensive sustainable development evaluation questionnaire was developed and optimized using the fuzzy Delphi method to assess the participants' knowledge of and attitudes toward the SDGs. Our results reveal that the digital and non-digital board game both improve students' knowledge and attitude toward sustainable development. However, the digital board game was more effective than the non-digital board game.

Keywords: sustainable development goals; sustainable development education; game-based learning; digital game-based learning

check for updates

Citation: Ho, S.-J.; Hsu, Y.-S.; Lai, C.-H.; Chen, F.-H.; Yang, M.-H. Applying Game-Based Experiential Learning to Comprehensive Sustainable Development-Based Education. *Sustainability* **2022**, *14*, 1172. https://doi.org/10.3390/su14031172

Received: 25 November 2021
Accepted: 18 January 2022
Published: 20 January 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

1.1. Sustainable Development Goals

The Industrial Revolution has improved production efficiency and driven economic development and globalization. With these advances, serious economic, social, and environmental problems have also emerged. Therefore, the United Nations formulated the Sustainable Development Goals (SDGs) in 2015. The 17 objectives encompass environmental, social, and economic aspects that are intended to guide countries and regions around the world in building a world with the following characteristics: sufficient energy; abundant natural resources; equity for all; and no poverty, hunger, discrimination, violence, or exploitation. In this world, the disadvantaged can lead a smooth life and are respected, and humans and nature live in harmonious coexistence. The climate is pleasant and suitable for the existence of all living beings [1]. The SDGs have gained widespread attention, and many international organizations [2–4] have launched collaborative programs. Furthermore, various countries have successively proposed policies for local development [5,6], demonstrating a shared commitment to realizing the SDGs.

However, the promotion of sustainable development extends beyond state obligations; it is the right and responsibility of all citizens. In this regard, successful promotion is

possible only with the concerted efforts of citizens, societies, states, and the international community. To make people aware of the criticalness and urgency of sustainable development and to make them work together to seek long-term peace and prosperity for human beings and the Earth, education is the key. Education can raise public awareness of and change attitudes toward sustainable development issues, thereby fostering sustainable development–related values and behaviors. Education is also the key to improving people's skills in resolving environmental and development issues [7]. Education inspires problem awareness and leads to preplanning based on systematic thinking, thereby facilitating the making of responsible decisions and actions.

Because sustainable development is a highly complex issue concerned with balancing environmental, social, and economic aspects, the 17 SDGs should not be treated separately; they are interrelated [8]. Complex interdisciplinary concepts and knowledge must be acquired to foster a comprehensive understanding of the SDGs and the practice of sustainable development. For citizens to become practitioners and promoters of SDGs, education on sustainable development should be universally provided, thereby enabling learners to transform and reshape the world [9].

To disseminate information on the SDGs, teachers should develop an instructional method to promote engagement as well as focused and spontaneous participation in learning. Conventional teaching methods fail to stimulate learning motivation [10]. Motivating learners to actively engage in learning has become a major challenge in sustainable development education. Game-based learning can augment the fun of learning, encourage participation and spontaneity, and enhance concentration [11]. This learning strategy helps students hone their planning and problem-solving skills and sparks creativity and strengthens intrinsic learning motivation [12], thereby mitigating the problem of passive learning common in conventional teaching and effectively improving learning outcomes [13]. Thus, game-based learning is considered a highly effective mode of learning [14]. Accordingly, it should be incorporated into sustainable development education [15].

1.2. Game-Based Learning

In game-based learning, knowledge or concepts are integrated into games from which learners naturally acquire relevant concepts or knowledge [16]. A similar concept, serious games, refers to games designed for more than entertainment; they are intended to help learners develop new skills and knowledge. Such games touch on serious issues in education, medicine, military affairs, and corporate training [17]. Following advances in information technology, digital devices such as computers and smartphones have become ubiquitous. Their integration into our everyday lives has inspired teachers and researchers in relevant fields to combine education and information technology in the form of digital game-based learning.

These terms commonly emphasize the integration of entertainment and learning. Education, training, and the propagation of ideas are realized through games and the playfulness and dynamism that attract learners. To avoid terminological confusion, in this paper, game-based learning encompasses all learning methods with these characteristics. Digital game-based learning refers to game-based learning employing computers, cell phones, and other technologies as the game medium. Non-digital game-based learning refers to the conventional form of game-based learning in which technologies are not typically used.

Numerous studies have confirmed that game-based learning can enhance public knowledge on social issues, change attitudes toward sustainable development and related subjects [18–21], increase motivation and facilitate different kinds of learning [16], and equip learners with the complex, cross-disciplinary concepts and knowledge necessary for the practice of sustainable development [22–26]. Based on its various advantages, game-based learning should be integrated into education [15] to deliver knowledge on comprehensive sustainable development to the public. However, themes in game-based learning relating to sustainable development education primarily focus on the environ-

ment [27] or emphasize one particular goal, precluding the full understanding of all aspects of sustainable development [28].

To conduct an in-depth evaluation on games used in sustainable development education, sustainable development–themed games reviewed by Liarakou et al. [29], dos Santos et al. [30], and Stanitsas et al. [28] were sorted. After duplicates were removed, 156 games remained, of which only 35 covered all three aspects of sustainability. Because some games were launched over 20 years ago, some of them are no longer accessible. In some cases, URLs to web pages listing relevant information had been removed. Few games for comprehensive sustainable development education are freely accessible to the public. Moreover, they are typically flawed; for instance, their settings may deviate considerably from reality. The evaluation methods may also be questionable, as exemplified by the following examples of digital game-based learning.

Through the SAMBA Role Play [31] game, Boissau et al. demonstrated to northern Vietnamese farmers the difference in outcomes of planting upland rice versus cash crops. Wooden cubes of a particular color simulated a particular type of land use, such as forests, rice paddies, and cash crops. The participants were requested to allocate their land, labor, and capital. Through the game mechanism, the farmers understood the environmental damage caused by riverside deforestation. However, given the small sample size (N = 10), no quantitative analysis was performed.

Chappin et al. [18] incorporated conditions similar to those in Catan Scenarios: Oil Springs into Settlers of Catan, a popular board game. Through the simulation of the effects of petroleum extraction, including the economic benefits and environmental pollution it brings, public understanding of sustainability problems, including externalities, resource dependence, and the tragedy of the commons, was deepened. The objective was to inspire changes in public attitudes and behavior regarding sustainable development. Through qualitative analysis, the researchers confirmed that learners' attitudes toward sustainability underwent shifts after the acquisition of sustainability knowledge, which, in turn, affected their sustainability-related behavior. However, due to an overemphasis on the effects of oil extraction in that study, the value of renewable energy appears to be overshadowed by cheaper and more powerful nonrenewable energy sources [32].

In the LSD board game [33], the effects assigned to various tiles are used to implement sustainable development in a community, with the aim of making learners aware of issues concerning urban development and environmental protection and changing their attitudes accordingly. Torres et al. mentioned that tests conducted on the game were not designed to demonstrate its effectiveness but were instead intended to reveal its strengths and weaknesses and promote improvement. Thus, although the researchers recorded the test-related data, they did not publish them in their study.

Examples of digital game-based learning are presented as follows. Through simulation, Stop Disasters! [34] teaches learners about the potential risks of disasters such as tsunamis, hurricanes, wildfires, earthquakes, and floods and disseminates knowledge on disaster prevention, monitoring, and mitigation strategies. Pereira et al. reported that a focus on wildfire scenarios promoted the development of knowledge on wildfire prevention. Moreover, most of the learners considered the game enjoyable. According to Stanitsas et al. [28], however, Stop Disasters! covers only two aspects of the SDGs: society and the environment. The game is less comprehensive in this regard; specifically, the learning themes address only SDG 9 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities), and SDG 13 (climate action).

In Enercity [19], learners are instructed to deploy measures for energy conservation, carbon reduction, and fossil fuel reduction. At the same time, they must determine how to generate more electricity to promote global economic development. The game endows learners with an awareness of the necessary balance between economy, energy, and environment. Through questionnaire analysis, Knol et al. observed that compared with those of the nonparticipants in the Enercity game, the game participants exhibited significant improvements in attitudes and behaviors regarding energy efficiency issues. However,

Soekarjo et al. [35] argued that because Knol et al. investigated only the posttest differences between the experimental and control groups, the results reported for game-attributed attitude changes may not be accurate or fully reflective of reality. Therefore, Soekarjo et al. reevaluated Enercity with an experimental group playing the game and a control group learning the same content through a PowerPoint file. The researchers conducted analyses of both a pretest and posttest on changes in the learners' knowledge and attitudes. Contrary to expectations, changes in the experimental group did not differ significantly from those of the control group. Furthermore, improvements in micro-level attitude were more substantial in the control group than in the experimental group.

In Irrigania, an irrigation simulation game developed by Seibert et al. [36], learners assume the role of farmers and irrigate their fields with rainwater, river water, or groundwater. Although water resources bring farmers profits, the excessive exploitation of water resources results in considerable reductions in both water level and profits. Learners must conceive means for balancing the moderate use of resources and the protection of personal interests. Knowledge on the tragedy of the commons was acquired, as was knowledge on the various effects and consequences of using diverse water resources. Ertsen et al. noted that Seibert et al. did not publish game-related data. Moreover, the identical initial values of upstream and downstream farmers deviated from reality [37].

The flaws in the reviewed studies and games were noncomprehensive (Stop Disasters!), leading to a lack of definitively evaluated results due to the absence of quantitative analysis (SAMBA Role Play and LSD) and game settings divergent from reality (Catan Scenarios: Oil Springs and Irrigania). Thus, a self-developed game was employed in the present study.

We followed Kolb's experience learning theory in developing a game-based learning approach that delivers comprehensive information on SDGs. In consideration of the ongoing COVID-19 pandemic and its impediment to traditional learning, we developed a digital version of the game and compared the effects of non-digital and digital game-based learning. The role of the teacher was different in the non-digital and digital game. For the non-digital version of the game, teachers gave a tutorial and led discussion and interaction. For the digital game, students watched a video tutorial and teachers monitored the game-playing process from behind the scenes, giving students the freedom to lead the activity.

2. Methods

To deliver knowledge on the SDGs and related concepts, a non-digital board game with the 17 SDGs as its themes was developed based on the experiential learning theory. According to the themes, rules, and artistic style of the non-digital game, a digital version was produced. Moreover, a questionnaire was designed to evaluate learners' knowledge and attitudes toward the SDGs. Its reliability and validity were improved through the fuzzy Delphi method.

2.1. Development of the Non-Digital Version of the Game

Kolb's experiential learning theory encourages students to learn actively and to hone skills such as critical thinking and reflection by examining their own feelings, thoughts, and experiences. In the present context, experiential learning aims to prompt the cultivation of knowledge on sustainable development and motivate relevant behaviors [38]. Sustainable development education should center on equipping students with skills relating to communication, innovation, and critical thinking. Experiential learning enables students to learn to communicate and collaborate with others, acquire valuable interpersonal skills, and solve complex problems [39].

The design of the SDG-themed board game cards simulated the real world; the cards' content and graphics were designed and classified according to the 5Ps of the SDGs, namely people, prosperity, planet, peace, and partnership. The 2018 Environmental Performance Index [40] and Countryeconomy.com (accessed on 12 January 2020) [41] were also referred to. As a result, five values were determined for the national roles, namely people, prosperity,

planet, governance, and partnership; ten national roles were designed that encompass developed, undeveloped, and developing countries.

Herein, students assumed the role of national leader. With SDG implementation as the main task, they participated in collaboration, discussion, and research, analyzing the adoption of various cross-domain policies on the game cards. The game allowed learners to undergo the experiential learning cycle proposed by Kolb: the processes of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Figure 1).

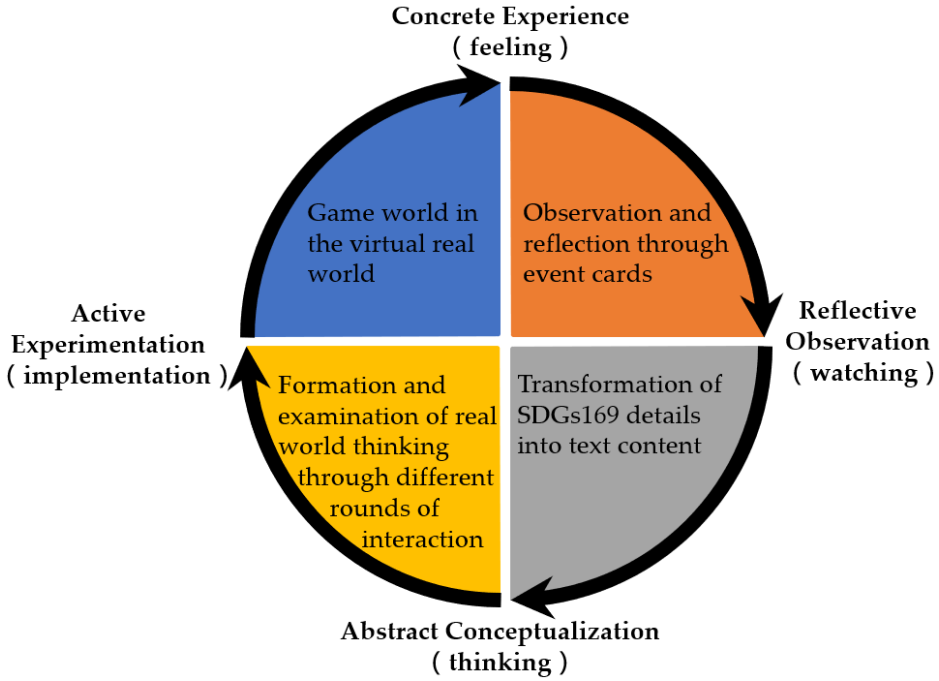

Figure 1. Experiential learning cycle.

2.1.1. Concrete Experience

According to Kolb, experience is the origin of learning and knowledge acquisition. Thus, to promote learning, individuals should be completely immersed in the stage of concrete experience. However, if sustainable development is taught only through the traditional lecture method, learners can hardly gain relevant experience in memorization and recitation.

A virtual game world was designed to encompass countries in various conditions. Specifically, five indexes on the economic, social, environmental, governance, and diplomatic conditions of each country were established. Learners were requested to play the countries' leaders and lead their countries to implement the SDGs assigned to them.

2.1.2. Reflective Observation

In the stage of reflective observation, learners were asked to review their experience in playing the game, ponde its meaning, consider the actions taken to solve the problem, and share and discuss national policy development with other students through a simulated national policy meeting. Various development cards (Figure 2), diplomacy cards (Figure 3), and event cards (Figure 4) were designed for the game. The development, diplomacy, and event cards were designed to (1) use 5Ps as the framework; (2) correspond with the implication of one of the 17 SDGs.

The development cards represented the process a country undergoes during its development. The development cards covered national policies regarding river rectification, education, the construction of thermal power plants, and artificial intelligence research.

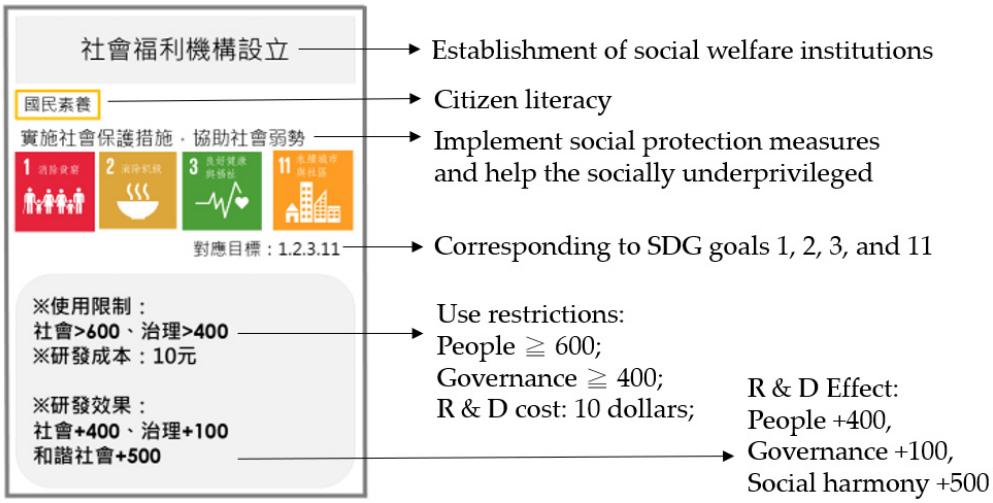

Figure 2. Development cards (Figure 2 presents a development card representing the establishment of social welfare institutions and indicating correspondence with Goal 1, 2, 3, and 11.).

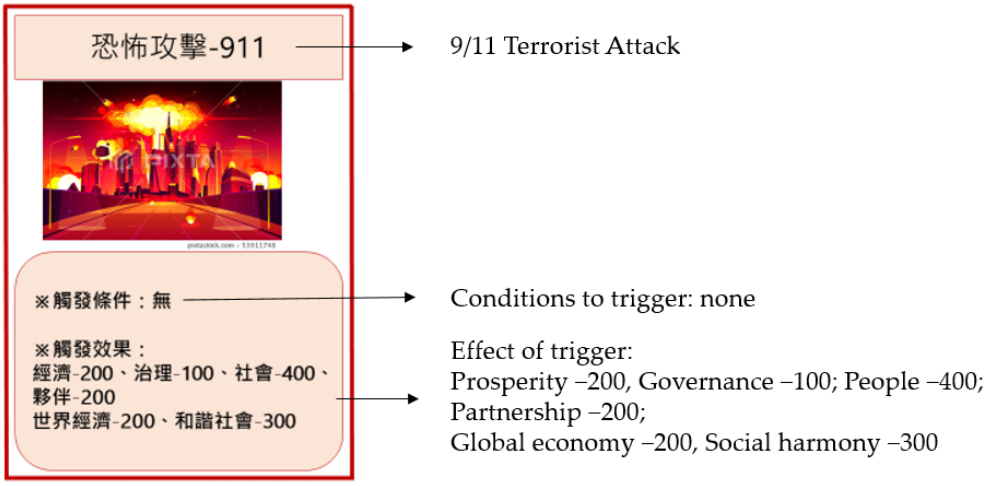

Figure 3. Diplomacy cards (Figure 3 presents a diplomacy card representing the occurrence of the 9/11 terrorist attack.).

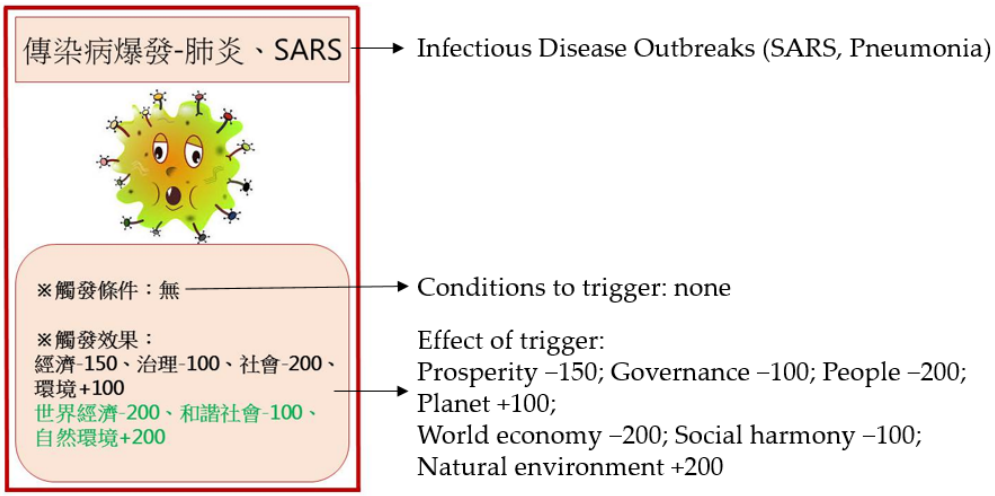

Figure 4. Event cards. (Figure 4 presents an event card representing outbreaks of infectious diseases such as SARS and pneumonia.).

Designed according to themes of international conventions or world conferences, the diplomacy cards addressed international or diplomatic policies formulated through the signing of international agreements on trade, carbon emissions, human rights, war, and the illegal waste trade.

Moreover, event cards are randomly triggered in the game. The 23 event cards were designed to correspond to the 17 SDGs. Events that shocked the world taking place since the start of the industrial revolution and involving the planet, people, or prosperity were chosen, such as the air pollution disaster in the Meuse Valley in 1930, the industrial wastewater pollution causing Minamata disease in Japan in 1956, the Chernobyl nuclear accident in 1980, the SARS coronavirus outbreak in 2003, the financial crisis in 2008, and the Gulf of Mexico oil spill in 2010. During the game, event cards covering both natural and manmade calamities such as large-scale natural disasters, extreme climate, infectious disease outbreaks, and marine oil spills were randomly triggered.

These cards represented simulations of national and diplomatic policy implementation as well as occurrences of disasters or accidents in the real world. The use of these policy cards affected both national and global values on the economy, society, environment, governance systems, and diplomatic relations. In reflecting on the reasons for variations in these values, learners understood the SDGs' impacts on both a national and global scale.

2.1.3. Abstract Conceptualization

The stage of abstract conceptualization emphasized the integration of new and old concepts, thereby creating new dimensions of thought. Thus, on each of the policy and event cards, relevant concepts were textually or graphically presented to enhance understanding. Learners synthesized the information presented on a card by comparing the effects of a card on the aspects of economy, society, environment, governance systems, and diplomatic relations in the countries considered.

2.1.4. Active Experimentation

The stage of active experimentation emphasized practical learning. Learners conducted experimental simulations during the game. According to the experience and knowledge acquired in the previous session, they adjusted the corresponding national policies and competed and collaborated with other countries in a timely manner. Thus, under national and global development, the various aspects of each country were balanced.

2.2. Development of the Digital Board Game

A digital version of the board game was developed based on the mechanism, procedures, and art style of the non-digital game (Figure 5).

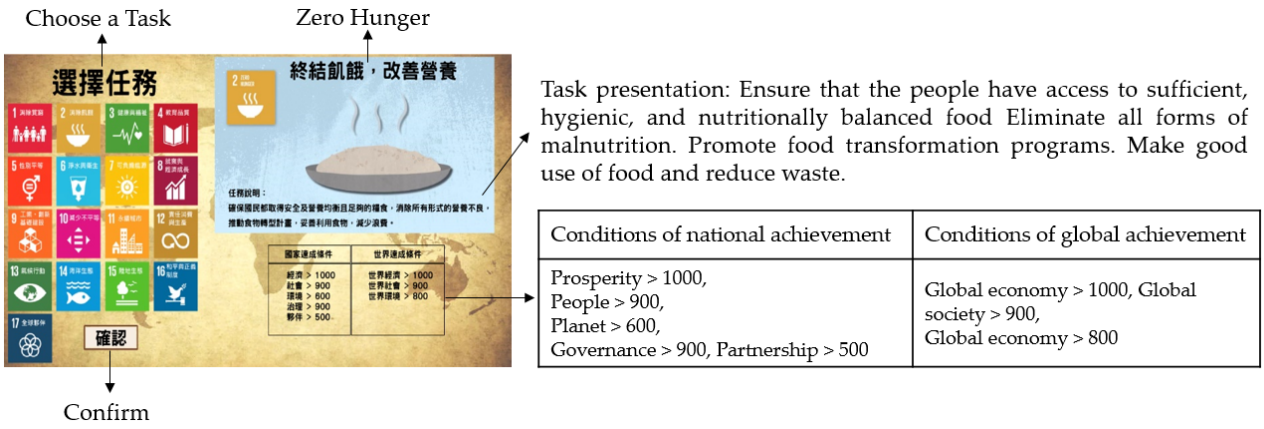

Figure 5. Task options page of the digital version of the game. (Figure 5 presents the goal options page of the digital version of the game. From the 17 goals, the learner can freely select the goals to achieve in the current game session.).

The digital version of the game differed from the non-digital version in its multimedia effects; background music, sound effects, and animation were used to present the teaching material. When the values of the countries changed or emergencies occurred, sound effects and animations of thunder and birdsongs were employed to deepen learners' impression of the consequences of these events. Moreover, to simulate the real world, the non-digital game was designed to have greater complexity; therefore, learners must understand the values held by their countries and the rationale for scoring before making a move. The digital version also allowed learners to formulate rules in advance in the software. The system automatically adjusted the countries' data and scores in response to the policies implemented by learners.

2.3. Questionnaire Design

To understand learners' experience of the game and determine whether their perceptions of and attitudes toward SDGs changed, a questionnaire was developed to address the 17 SDGs and serve as a reference for the future promotion of sustainable development education. To enhance the reliability of the questionnaire, the fuzzy Delphi method was used for verification. We referred to the calculation procedures of Chen et al. [42]. The steps are listed as follows.

Step 1: Formulate a questionnaire by referring to the 17 SDGs.

Step 2: Invite 10 experts in relevant fields to evaluate the questionnaire. The experts scored each item on a 5-point Likert scale with three interval values, namely the most optimistic awareness value, the most conservative awareness value, and the optimal awareness value.

Step 3: Sort the evaluation values (Appendix A Table A1). Exclude extreme values (those outside two standard deviations from the mean). Calculate the maximum (O_U^i), minimum (O_L^i), and geometric mean (O_M^i) of the most optimistic awareness value, as well as the maximum (C_U^i), minimum (C_L^i), and geometric mean (C_M^i) of the most conservative awareness value.

Step 4: For each item, establish the respective triangular fuzzy numbers of its optimistic awareness value, $O^i = (O_U^i, O_L^i, O_M^i)$, and its conservative awareness value, $C^i = (C_U^i, C_L^i, C_M^i)$.

Step 5: Use the overlapping area of the double triangular fuzzy numbers to determine whether expert consensus is reached. The possible states of the gray area are listed as follows.

1. A nongray area: No overlap between the triangular fuzzy numbers of the most optimistic and most conservative awareness values are observable; expert consensus is established. The formula for G^i, the expert consensus value of an evaluation item, is $G^i = (C_M^i + O_M^i)/2$.
2. A gray area exists, but the experts' opinions are less divergent. The gray area value Z^i is less than M^i, the interval of the geometric mean between the most optimistic and most conservative awareness values, suggesting that regardless of the fuzzy area between the experts' opinions, the difference between the opinions of the experts presenting extreme values and those of the other experts is moderate. The formula for G^i, the expert consensus value of the evaluation item, is expressed as follows:

$$\text{Fuzzy set } F^i(X_j) = \int_x \{min[C^i(X_j), O^i(X_j)]\} d_x$$
$$G^i = \{X_J | max\ u_{F^i}(x_j)\}$$

3. A gray area exists, and the divergence in expert opinions is considerable. A gray area value Z^i is greater than the interval of the geometric mean, M^i, between the most optimistic and most conservative awareness values. Thus, the item should be revised and re-evaluated. Repeat Steps 1 to 4 until all items converge.

3. Experimental Process and Analysis of Results

3.1. Experimental Process

The participants, 225 Taiwanese students aged 10 to 17 years, were divided into two groups to play the non-digital and digital versions of the game (n = 95 and 130, respectively). As displayed in Table 1, the experimental process comprised four stages. In the first stage, the questionnaire was administered as a pretest. In the second stage, the digital group viewed a video as an introduction to SDGs and the game, whereas the non-digital group received a PowerPoint lecture on the same information. The game was played in the third stage. The digital group played the game on a computer. Each participant was assigned to a computer. As for the non-digital group, the students were divided into groups of approximately six and played the game using cards and other props. In the fourth stage, the questionnaire was administered as a posttest, and the pretest–posttest differences in the students' perception, knowledge, and attitude regarding SDGs were examined. Furthermore, the students' opinions on game feel were collected. The entire experiment lasted 80 min.

Table 1. Experiment duration.

Experimental Stage	Non-Digital Teaching Duration (Min)	Digital Teaching Duration (Min)
Pretest	10	10
Introduction to sustainable development and game instructions	30	10
Gaming	30	50
Posttest	10	10

To compare the differences more clearly between digital and non-digital learning, in the course using the digital version, students watched an instructional video and played the game on their personal computer, without teachers' tutorial or explanation.

3.2. Experimental Analysis

The pretest and posttest scores were organized into interaction graphs and are presented in Figures 6–8. Moreover, the questionnaire results were submitted to a paired sample t-test, and the test results were organized according to the categories of perception, knowledge, and attitude, as presented in Tables 2–4. Interaction graphs (Figures 6–8) revealed that both the digital and non-digital versions of the game resulted in improvements to perception, knowledge, and attitude regarding SDGs. Overall, the participants expressed that the game allowed them to become more familiar with the SDGs.

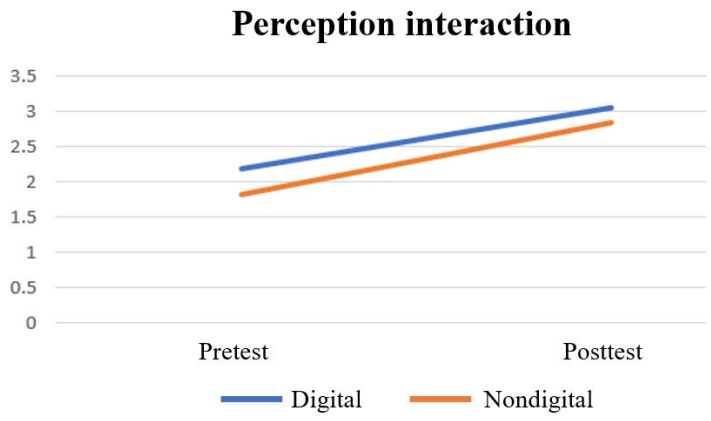

Figure 6. Perception interaction graph.

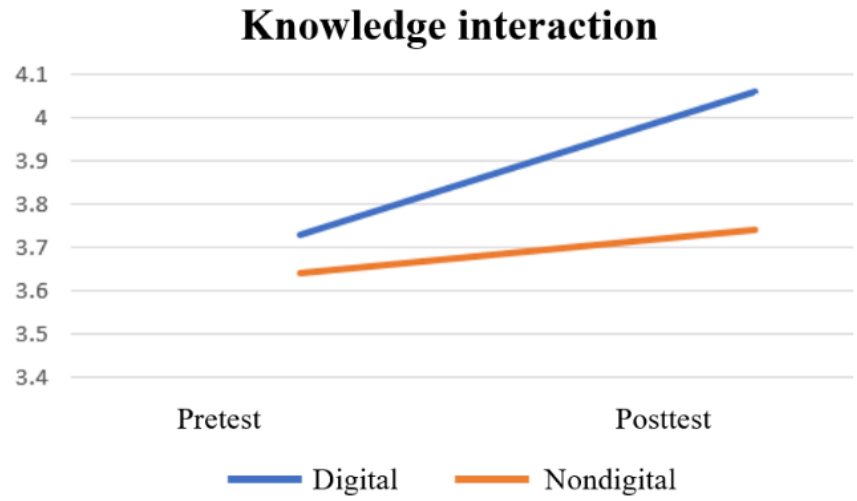

Figure 7. Knowledge interaction graph.

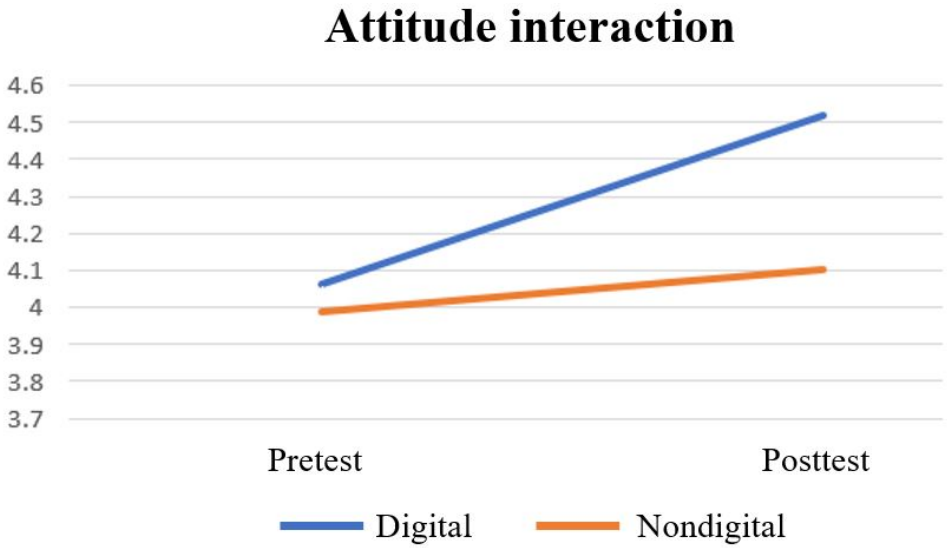

Figure 8. Attitude interaction graph.

Table 2 presents the results of the paired sample *t*-test for the perception difference between the non-digital and digital board game groups. Significant differences in perception between the pretest and posttest in the following groups were observed: primary school ($p < 0.001$, d = −1.082), junior high school ($p < 0.001$, d = −2.533), and senior high school ($p = 0.006$, d = −0.646) using the non-digital version, and primary school ($p < 0.001$, d = −0.964) and senior high school ($p = 0.004$, d = −1.455) using the digital version. Figure 6 depicts no significant perception progress differences between digital and non-digital groups after treatment.

Table 3 presents the results of the paired sample *t*-test for the knowledge difference between the non-digital and digital board game groups. A significant difference in knowledge between the pretest and posttest in the following groups were observed: senior high school ($p < 0.001$, d = −1.160) used the non-digital version and primary school ($p < 0.001$, d = −1.307) and senior high school ($p < 0.001$, d = −1.731) used the digital version. Figure 7 depicts no progress differences in the knowledge interaction before treatment. Moreover, the difference between the digital and non-digital groups in the posttest was significant.

Table 2. *T*-test results for the perception difference between the non-digital and digital board games groups.

		Pretest		Posttest		Degrees of Freedom	*t*-Test Result	*p*	Effect Size (*d*)
		Mean	Standard Deviation	Mean	Standard Deviation				
Non-digital board game group	Primary school	1.380	0.535	2.380	1.193	44	−5.173	<0.001	−1.082
	Junior high school	1.710	0.463	3.480	0.873	20	−8.556	<0.001	−2.533
	Senior high school	2.590	0.825	3.070	0.651	28	−2.985	0.006	−0.646
Digital board game group	Primary school	2.180	0.991	3.160	1.041	72	−6.501	<0.001	−0.964
	Junior high school	2.820	0.588	3.180	0.853	21	−1.702	0.104	−0.491
	Senior high school	2.750	0.683	3.960	0.957	15	−3.416	0.004	−1.455

Table 3. *T*-test for knowledge difference between the non-digital and digital board game groups.

		Pretest		Posttest		Degrees of Freedom	*t*-Test Result	*p*	Effect Size (*d*)
		Mean	Standard Deviation	Mean	Standard Deviation				
Non-digital board game group	Primary school	3.641	0.331	3.586	0.414	44	0.636	0.528	0.147
	Junior high school	3.714	0.357	3.667	0.426	20	0.484	0.634	0.120
	Senior high school	3.591	0.306	4.042	0.457	28	−11.669	<0.001	−1.160
Digital board game group	Primary school	3.795	0.048	4.250	0.490	72	−6.324	<0.001	−1.307
	Junior high school	3.769	0.351	3.713	0.325	21	0.562	0.580	0.166
	Senior high school	3.835	0.401	4.497	0.363	15	−4.996	<0.001	−1.731

Table 4. *T*-test results for attitude difference between the non-digital and digital board game groups.

		Pretest		Posttest		Degrees of Freedom	*t*-Test Result	*p*	Effect Size (*d*)
		Mean	Standard Deviation	Mean	Standard Deviation				
Non-digital board game group	Primary school	3.717	0.566	3.867	0.661	44	−1.138	0.261	−0.244
	Junior high school	4.179	0.662	4.393	0.528	20	−1.353	0.191	−0.357
	Senior high school	4.267	0.491	4.241	0.475	28	1.000	0.326	0.054
Digital board game group	Primary school	4.062	0.613	4.318	0.555	72	−3.001	0.004	−0.438
	Junior high school	3.920	0.683	4.148	0.544	21	−1.324	0.200	−0.369
	Senior high school	4.547	0.493	6.531	0.584	15	−15.752	<0.001	−3.671

Table 4 presents the results of the paired sample *t*-test for the attitude difference between the non-digital and digital board game groups. Significant differences in attitude between the pretest and posttest were observed in the primary school group ($p = 0.004$, d = −0.438) and senior high school group ($p < 0.001$, d = −3.671) using the digital version. Figure 8 depicts no progress differences in the attitude interaction before treatment. Moreover, the difference between digital and non-digital groups in the posttest was significant.

Finally, we conducted a two-way analysis of variance (ANOVA) on whether the board game version (non-digital or digital) and learners' age affected game feel. As can be seen in Table 5, both the board game version (F (1, 200) = 4.986, $p = 0.027$, η_pˆ(2) = 0.024) and learners' age (F (2, 200) = 6.368, $p = 0.002$, η_pˆ(2) = 0.060) significantly affected game feel; learners' age affected game feel for the digital and non-digital version in game-based learning, and younger learners held a higher preference for the digital version of the educational game.

Table 5. ANOVA on the affect of board game version (non-digital or digital) and age on game feel.

Source of Variance	*SS*	*Df*	*MS*	*F*	*p*	η_p^2
A Board game version	3.006	1	3.006	4.986	0.027	0.024
B Age	7.680	2	3.840	6.368	0.002	0.060
A × B	27.486	2	13.743	22.791	<0.001	0.186
Error	120.597	200	0.603			
Sum	152.454	205				

After the experiment was completed, learners spontaneously stayed and shared their throughts and feelings. Their feedback was categorized into three categories, namely "knowledge and ideas", "operation issues", and "game feel", as presented in Table 6.

Learners using the non-digital version gave more feedback in the "knowledge and ideas" category, and their feedback was more in-depth. In our view, the reason for this lies in the non-digital gaming process in which learners shared experiences with other players, increasing their reflections; learners were given sufficient time to think about the knowledge and ideas the game intended to deliver [43]. Therefore, learners using the non-digital version could generally respond in ways that involved a more profound understanding of the goals behind the game and the SDGs.

In the category of "operation issues" feedback, learners using the digital version expressed that the game pace was too fast, which probably prevented them from making the best decisions. In contrast, learners using the non-digital version expressed that the game was somewhat complicated, probably because, in the digital version, the game rules were programmed into the system and players did not have to manage them [44], whereas players of the non-digital version of the game had to understand all the rules and calculate the scores by hand [45].

In the "game feel" category, most of the feedback was given by players of the digital version. They generally liked the multimedia effects, such as the sound effects and animations, and better appreciated the fun of the game, which was mentioned less often by players of the non-digital version. This difference is attributable to the digital version presenting teaching materials via lively multimedia, including music, images, and animations, immersing learners in the learning process and enhancing their interest, impression, and memory of the content while decreasing their cognitive load [46]. Consequently, feedback from participants in the digital version most often mentioned the impact of the multimedia effects.

Table 6. Participants' feedback.

	Digital Version	Non-Digital Version
Knowledge and ideas	A. When I began to fill out the pretest questionnaire, I only had a vague idea about sustainable development. After playing the board game, I came to see its varied aspects. B. It invites reflection on the importance of sustainability. I learned that one really needs to take care of many different aspects to achieve good national governance. C. I think it's quite fun, and I got to know more about sustainable development.	A. I learned that sustainable development requires efforts from every country and citizen. After all, one incident will affect the whole world through the butterfly effect. It will be hard to achieve sustainable development goals only by the effort of a few people. B. The game demonstrates the human mindset of seeking economic development by abruptly abandoning nature. Such a view is quite realistic, but it's imperative to change it. C. During the activity, I was reminded of the status quo of the world. Some countries are extremely rich and it's easier for them to achieve their goals. But, in the end, they still failed because global goals remained unachieved, which is actually the same as the status quo of our world. D. In the game, it was hard enough to attain a balance between Prosperity and the Planet, not to mention how hard this is in actual society. E. The activity was quite fun. The combination of the board game with the SDGs made me understand the content better. The connection with real life was really surprising to me.
Operation issues	A. The transition scenes in the game passed so fast that I couldn't make good decisions. Still, the game was quite fun, and I was especially delighted to see my resources increase.	A. The scale of the game is quite large, and the rules are a bit complex.
Game feel	A. For me, it was a nice game to play, and its sound effects make it even more fun to play. B. The entire game design was well-conceived. Also, the video and graphics were quite refined, and the sounds were well-made. C. The game itself is very meaningful as well as vivid and fun.	A. The game design was quite creative as well.

Moreover, the participants generally indicated that their game experience was excellent; they felt a strong sense of achievement in seeing the improvement of their countries' economic, social, and environmental indexes. The game deepened their understanding of sustainable development and presented the opportunity for a profound reflection on the importance of sustainable development.

As displayed in Table 6, most participants in the digital group enjoyed the use of the multimedia effects (e.g., sound effects and animation). The non-digital group held that the game allowed for the creation of associations and correspondence with the real world. Participants' feedback is organized in Table 6.

4. Conclusions

4.1. Discussion

Considering the scarcity of freely accessible games designed for comprehensive sustainable development education, we sought to promote SDG implementation through a self-developed game with SDGs as the theme and the experiential learning theory as its basis. The intent was to leverage the advantages of game-based learning to trigger the participants' motivation to learn about the SDGs [11], enhance their understanding of social issues [47], and thus, change their attitudes toward sustainable development issues [18].

Amid the ongoing COVID-19 pandemic, many schools have been compelled to suspend classes or switch to remote learning. We developed a digital version of the game in consideration of the fact that digital game-based learning is not spatiotemporally constrained. The aim was to allow learners interested in SDGs easy access to relevant information anytime and anywhere. Through the game development process and the examination of the learning outcomes, recommendations for game designers and educators were formulated.

Game-based learning changed the learners' perception, knowledge, and attitude regarding SDGs. This game, in combination with the accompanying questionnaire, constitutes an ideal tool for promoting understanding of the SDGs and influencing public opinion on sustainable development. According to the present design and instructional processes, the following recommendations are advanced:

(1) A longer amount of time should be allocated for introducing the non-digital version of the game to learners than for introducing the digital version.

The digital version of the game allowed players to program game rules. The non-digital version, which had a slower rhythm, precluded this operation [43]. Learners in the non-digital group must thoroughly understand the rules. Moreover, during the game, they must calculate their own scores. These procedures made the non-digital version of the game more time consuming than the digital version.

(2) Teachers should avoid asserting too much control over the gameplay process.

Teachers should appropriately manage the gaming speed as well as provide direction for discussion and thinking. Excessive intervention and playing the leader in game-related exchanges, discussions, and interactions are inappropriate. The instructional method generally used by most teachers in Taiwan consists in directly instilling information in students instead of guiding them in active learning. Moreover, direct conversation or activities with teachers is a source of considerable stress and anxiety for Taiwanese students in general [48], negating the advantage of game-based learning in engaging students in active learning. In a game environment in which students play the lead, students may be more motivated and willing to speak, thereby enhancing their learning outcomes through peer communication and exchanges.

(3) Scaffolding should be used to assist digital game-based learning.

In general, players of the digital version of the game encounter greater challenges in engaging in communication and exchange with their peers [43]. They cannot discuss with their peers or ask for advice in a timely manner should their lack of prior knowledge prevent them from understanding the perspectives presented in the game. Scaffolding

can be used to overcome these problems by assisting participants in creating connections between abstract concepts and concrete issues, thus facilitating problem-solving.

4.2. Limitations

Given the varying levels of emphasis placed on sustainable development issues in the included schools, the present study participants differed in terms of their prior knowledge of and attitudes toward sustainable development. Therefore, the experimental results might contain errors. However, sustainable development education has been incorporated into the curriculum of most schools in Taiwan; among all the schools in our experiment, only one junior high school that implemented digital game-based learning had not taught sustainable development lessons, placing students on a relatively even footing in terms of their background knowledge of sustainable development.

4.3. Conclusions

Herein, a game for comprehensive SDG education was developed. Given the ongoing COVID-19 pandemic, a digital version of the game was developed to enable participation free of spatiotemporal constraints. Overall, game-based learning improved the learners' perception, knowledge, and attitude regarding SDGs. Notably, a slight difference between the digital and non-digital groups to the extent of improvement between the pretest and posttest scores was detected. Most of the participants in the digital group outperformed the students in the non-digital group. To further compare the learning effects obtained in using the digital versus non-digital game media, the meaning behind this difference should be explored, and the differences between the modes of game-based learning through the digital and non-digital versions of the game should be examined.

4.4. Future Research

After the game was played, due to constraints of the school curricular arrangement, the present study could not conduct further follow-up learning activities such as facilitation, coaching, design, debriefing, reflection, and additional educational assignments. However, we believe that a well-facilitated debriefing session could help learners understand the varied positions and opinions of others and make reflections, thereby deepening social learning and the understanding of complex systems and enhancing learning at a deeper level [49].

Author Contributions: Conceptualization, S.-J.H. and F.-H.C.; Methodology, S.-J.H. and F.-H.C.; Writing—original draft, Y.-S.H.; Writing—review & editing, C.-H.L. and M.-H.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Questionnaire evaluation and values of expert opinions.

Goal Level	Dimension Level	Item Code	Item	Corresponding Goal	Mean			Minimum		Maximum		Range of Two Standard Deviations						Gray Area Verification Value		Convergence	Expert Consensus Value
					Conservatism Value	Optimism Value	Optimal Value	Conservatism Value	Optimism Value	Conservatism Value	Optimism Value	Conservatism Value		Optimism Value		Optimal Value		Z_i	M_i		
Evaluation of the effect of game-based learning on awareness of and attitude toward SDGs	A. Basic needs	A1	Eradication of poverty is the primary objective of the SDGs.	1	2.80	4.90	4.20	2	5	4	5	1.2	4.4	4.3	5.5	2.7	5.7	1.00	2.10	TURE	3.85
		A2	War is the main cause of famine and poverty.	1.2	2.70	4.70	4.00	2	4	4	5	1.1	4.3	3.8	5.6	2.2	5.8	0.00	2.00	TURE	3.70
		A3	Improving public health and people's opportunities to live a good life contribute to sustainable development.	3	2.70	4.40	4.00	1	4	4	5	0.5	4.9	3.1	5.7	2.0	6.0	0.00	1.70	TURE	3.55
		A4	Guaranteeing every child access to quality education paves the path to practicing sustainable development.	4.5	2.90	4.90	4.20	2	5	4	5	1.2	4.6	4.3	5.5	2.7	5.7	1.00	2.00	TURE	3.90
		A5	Realizing gender equality and encouraging women to participate in public affairs are crucial for implementing sustainable development.	5	2.60	4.70	4.10	1	4	3	5	0.6	4.6	3.8	5.6	2.2	6.0	1.00	2.10	TURE	3.65
		A6	Eliminating inequality and discrimination is irrelevant to the SDGs.	10.16	2.60	4.60	4.00	2	4	4	5	1.0	4.2	3.6	5.6	2.0	6.0	0.00	2.00	TURE	3.60
	B. Economic development	B1	Companies pursuing the sustainable development model can reap benefits in the long term.	9.12	2.40	4.30	3.70	2	4	3	5	1.1	3.7	3.0	5.6	2.4	5.0	1.00	1.90	TURE	3.35
		B2	Workforce productivity can be increased through sustainable economic growth, which contributes to economic and industrial growth and promotes everyone having a good job.	9	2.80	4.70	4.40	2	4	4	5	1.1	4.5	3.8	5.6	3.1	5.7	0.00	1.90	TURE	3.75
		B3	Economic development should be the priority of cities valuing sustainable development.	11	2.90	4.80	4.10	2	5	4	5	1.3	4.5	4.0	5.6	2.7	5.5	1.00	1.90	TURE	3.85
		B4	Governments should actively relocate polluting factories to industrial parks and establish green standards for products and clean production.	9.12	2.50	4.70	3.70	1	4	4	5	0.7	4.3	3.8	5.6	2.4	5.0	0.00	2.20	TURE	3.60
	C. Environmental sustainability	C1	Regarding the use of natural resources, human needs should be prioritized.	7.12,	2.80	4.90	4.20	2	5	3	5	1.6	4.0	4.3	5.5	3.0	5.4	2.00	2.10	TURE	3.85
		C2	I think everyone should be allowed to use as much water as they wish, according to their habits.	6	2.40	4.30	3.70	1	3	4	5	0.6	4.2	2.7	5.9	1.9	5.5	1.00	1.90	TURE	3.45

Table A1. *Cont.*

Goal Level	Dimension Level	Item Code	Item	Corresponding Goal	Mean			Minimum		Maximum		Range of Two Standard Deviations						Gray Area Verification Value		Convergence	Expert Consensus Value
					Conservatism Value	Optimism Value	Optimal Value	Conservatism Value	Optimism Value	Conservatism Value	Optimism Value	Conservatism Value		Optimism Value		Optimal Value		Z_i	M_i		
		C3	I believe that using more natural resources than necessary will not threaten the health and welfare of future generations.	7.12	3.00	4.90	4.40	2	3	4	5	1.5	4.5	4.3	5.5	3.4	5.4	1.00	1.90	TURE	3.66
		C4	Human activities for economic development are not a cause of climate change.	8.13	2.90	4.80	4.30	2	5	4	5	1.7	4.1	4.0	5.6	3.0	5.6	1.00	1.90	TURE	3.85
		C5	Land reclamation is an effective means to acquire land and has been implemented on a large scale in countries such as the Netherlands and Japan. Taiwan should follow their example.	14	2.10	4.20	3.40	1	4	4	5	0.1	4.3	3.0	5.4	1.6	5.2	0.00	2.10	TURE	3.15
		C6	Faced with extreme climates, all humans should have the ability to recover from disasters and make related adjustments and adaptations.	11.13	2.70	4.80	3.90	2	5	4	5	1.2	4.2	4.0	5.6	2.5	5.3	1.00	2.10	TURE	3.75
	D. Global partnerships	D1	Respect for other cultures is irrelevant to sustainable development.	10.16	2.20	4.50	3.50	1	4	3	5	0.5	3.9	3.2	5.8	1.7	5.3	1.00	2.30	TURE	3.35
		D2	All countries should cooperate to implement the United Nations' SDGs.	17	2.80	4.70	4.10	2	4	4	5	1.1	4.5	3.8	5.6	2.4	5.8	0.00	1.90	TURE	3.75
		D3	Everyone is responsible for creating a sustainable future which is healthy, diverse, and productive and has the right to enjoy it.	ALL	2.70	4.80	3.90	2	5	3	5	1.8	3.6	4.0	5.6	2.8	5.0	2.00	2.10	TURE	3.75
		D4	Both the Charter of the United Nations and the principles of international law endow a country with the right to exploit its own resources. Therefore, the international community should not boycott a country that cuts down its forests for economic development.	15.17	2.70	4.50	3.80	1	4	4	5	0.8	4.6	3.2	5.8	1.8	5.8	0.00	1.80	TURE	3.60
		D5	Fair trade is an effective means to promoting sustainable development.	10.12	2.60	4.60	4.10	1	4	4	5	0.8	4.4	3.3	5.9	2.7	5.5	0.00	2.00	TURE	3.60
	E. Attitudes toward sustainability	E1	We should strive to promote ideas of sustainable development.	ALL	2.90	4.80	4.20	1	5	4	5	0.9	4.9	4.0	5.6	2.7	5.7	1.00	1.90	TURE	3.85
		E2	Sustainable development includes reflection on and rejection of traditional production process.	ALL	2.60	4.50	3.80	2	3	4	5	1.0	4.2	2.9	6.1	3.0	4.6	1.00	1.90	TURE	3.52
		E3	Our actions today are necessary for ensuring the happiness of future generations.	ALL	3.60	5.00	4.70	3	5	4	5	2.6	4.6	5.0	5.0	3.8	5.6	1.00	1.40	TURE	4.30
		E4	Everyone should learn about the SDGs.	ALL	2.90	4.80	4.40	1	5	4	5	0.9	4.9	4.0	5.6	3.1	5.7	1.00	1.90	TURE	3.85

Table A1. *Cont.*

Goal Level	Dimension Level	Item Code	Item	Corresponding Goal	Mean			Minimum		Maximum		Range of Two Standard Deviations						Gray Area Verification Value		Convergence	Expert Consensus Value
					Conservatism Value	Optimism Value	Optimal Value	Conservatism Value	Optimism Value	Conservatism Value	Optimism Value	Conservatism Value		Optimism Value		Optimal Value		Z_i	M_i		
	F. Game feel	F1	I think this game is fun.		3.22	5.33	4.67	2	4	4	5	1.3	5.1	3.9	6.7	3.1	6.3	0.00	2.11	TURE	4.28
		F2	When playing the game, I was very focused.		3.11	5.33	4.44	2	4	4	5	1.3	5.0	3.9	6.7	2.8	6.0	0.00	2.22	TURE	4.22
		F3	If given the chance, I would play the game again.		3.22	5.33	4.67	1	5	4	5	1.1	5.3	3.7	7.0	2.6	6.7	1.00	2.11	TURE	4.28
		F4	I learned a lot through this game.		3.44	5.22	4.89	3	4	4	5	2.1	4.7	4.0	6.4	3.3	6.5	0.00	1.78	TURE	4.33
		F5	After the game, I might change my attitude toward life in my daily living for the sake of sustainable development.		3.44	5.44	4.89	3	5	4	5	2.1	4.7	4.2	6.7	2.9	6.9	1.00	2.00	TURE	4.44

References

1. United Nations Department of Economic and Social Affairs. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2016.
2. United Nations Economic and Social Commission for Asia and the Pacific. Regional road map for implementing the 2030 agenda for sustainable development in Asia and the Pacific. In Proceedings of the Fourth Asia-Pacific Forum on Sustainable Development, Bangkok, Thailand, 29–31 March 2017; United Nations Economic and Social Commission for Asia and the Pacific: Bangkok, Thailand, 2017.
3. NU. CEPAL. *Horizons 2030: Equality at the Centre of Sustainable Development*; NU. CEPAL: Mexico City, Mexico, 2016.
4. Sustainable Development—Baltic 2030. Available online: https://www.cbss.org/sustainable-prosperous-region/egsd-baltic-2030-2/ (accessed on 28 September 2019).
5. NITI Aayog. *Three Year Action Agenda (2017–18 to 2019–20)*; NITI Aayog, Government of India: New Delhi, India, 2017; pp. 319–330.
6. UK Department for International Development. *Agenda 2030: Delivering the Global Goals*; UK Department for International Development: London, UK, 2017. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603500/Agenda-2030-Report4.pdf (accessed on 28 September 2019).
7. UNCED. Agenda 21, Chapter 36. 1992. Available online: http://www.un.org/esa/dsd/agenda21/ (accessed on 28 September 2019).
8. Kioupi, V.; Voulvoulis, N. Education for Sustainable Development: A Systemic Framework for Connecting the SDGs to Educational Outcomes. *Sustainability* **2019**, *11*, 6104. [CrossRef]
9. Kyle, W.C. Expanding our views of science education to address sustainable development, empowerment, and social transformation. *Discip. Interdiscip. Sci. Educ. Res.* **2020**, *2*, 2. [CrossRef]
10. Vergara, D.; Paredes-Velasco, M.; Chivite, C.; Fernández-Arias, P. The challenge of increasing the effectiveness of learning by using active methodologies. *Sustainability* **2020**, *12*, 8702. [CrossRef]
11. Pesare, E.; Roselli, T.; Corriero, N.; Rossano, V. Game-based learning and gamification to promote engagement and motivation in medical learning contexts. *Smart Learn. Environ.* **2016**, *3*, 5. [CrossRef]
12. Safapour, E.; Kermanshachi, S.; Taneja, P. A Review of Nontraditional Teaching Methods: Flipped Classroom, Gamification, Case Study, Self-Learning, and Social Media. *Educ. Sci.* **2019**, *9*, 273. [CrossRef]
13. Mayo, M.J. Games for science and engineering education. *Commun. ACM* **2007**, *50*, 30–35. [CrossRef]
14. Bevilacqua, M.; Ciarapica, F.E.; Mazzuto, G.; Paciarotti, C. "Cook &Teach": Learning by playing. *J. Clean. Prod.* **2015**, *106*, 259–271.
15. Dieleman, H.; Huisingh, D. Games by which to learn and teach about sustainable development: Exploring the relevance of games and experiential learning for sustainability. *J. Clean. Prod.* **2006**, *14*, 837–847. [CrossRef]
16. Plass, J.L.; Homer, B.D.; Kinzer, C.K. Foundations of game-based learning. *Educ. Psychol.* **2015**, *50*, 258–283. [CrossRef]
17. Susi, T.; Johannesson, M.; Backlund, P. *Serious Games: An overview*; School of Humanities and Informatics, University of Skövde: Skövde, Sweden, 2007.
18. Chappin, E.J.; Bijvoet, X.; Oei, A. Teaching sustainability to a broad audience through an entertainment game—The effect of Catan: Oil Springs. *J. Clean. Prod.* **2017**, *156*, 556–568. [CrossRef]
19. Knol, E.; De Vries, P.W. EnerCities—A Serious Game to Stimulate Sustainability and Energy Conservation: Preliminary Results. *eLearning Papers*. 2011. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1866206 (accessed on 28 September 2019).
20. Janakiraman, S.; Watson, S.L.; Watson, W.R. Using Game-based Learning to Facilitate Attitude Change for Environmental Sustainability. *J. Educ. Sustain. Dev.* **2018**, *12*, 176–185. [CrossRef]
21. Bilancini, E.; Bconcinelli, L.; Di Paolo, R. Game-Based Education Promotes Sustainable Water Use. *Res. Sq.* **2021**. [CrossRef]
22. Learmonth, G.P.; Smith, D.E.; Sherman, W.H.; White, M.A.; Plank, J. A practical approach to the complex problem of environmental sustainability: The UVa Bay Game. *Innov. J.* **2011**, *16*, 1–8.
23. Schulze, J.; Martin, R.; Finger, A.; Henzen, C.; Lindner, M.; Pietzsch, K.; Werntze, A.; Zander, U.; Seppelt, R. Design, implementation and test of a serious online game for exploring complex relationships of sustainable land management and human well-being. *Environ. Model. Softw.* **2015**, *65*, 58–66. [CrossRef]
24. Jouan, J.; De Graeuwe, M.; Carof, M.; Baccar, R.; Bareille, N.; Bastian, S.; Brogna, D.; Burgio, G.; Couvreur, S.; Cupiał, M.; et al. Learning Interdisciplinarity and Systems Approaches in Agroecology: Experience with the Serious Game SEGAE. *Sustainability* **2020**, *12*, 4351. [CrossRef]
25. Fabricatore, C.; López, X. Sustainability Learning through Gaming: An Exploratory Study. *Electron. J. e-Learn.* **2012**, *10*, 209–222.
26. Langendahl, P.-A.; Cook, M.; Mark-Herbert, C. Exploring gamification in management education for Sustainable Development. *Creat. Educ.* **2017**, *8*, 2243–2257. [CrossRef]
27. Hallinger, P.; Wang, R.; Chatpinyakoop, C.; Nguyen, V.-T.; Nguyen, U.-P. A bibliometric review of research on simulations and serious games used in educating for sustainability, 1997–2019. *J. Clean. Prod.* **2020**, *256*, 120358. [CrossRef]
28. Stanitsas, M.; Kirytopoulos, K.; Vareilles, E. Facilitating sustainability transition through serious games: A systematic literature review. *J. Clean. Prod.* **2019**, *208*, 924–936. [CrossRef]
29. Liarakou, G.; Sakka, E.; Gavrilakis, C.; Tsolakidis, C. Evaluation of serious games, as a tool for education for sustainable development. *Eur. J. Open Distance E-Learn.* **2012**. Available online: http://www.eurodl.org/?article=546 (accessed on 28 September 2019).

30. Dos Santos, A.D.; Strada, F.; Bottino, A. Approaching sustainability learning via digital serious games. *IEEE Trans. Learn. Technol.* **2018**, *12*, 303–320. [CrossRef]
31. Boissau, S.; Anh, H.L.; Castella, J.-C. The SAMBA Role Play Game in Northern Vietnam. *Mt. Res. Dev.* **2004**, *24*, 101–105. [CrossRef]
32. Fjællingsdal, K.S.; Klöckner, C.A. Green Across the Board: Board Games as Tools for Dialogue and Simplified Environmental Communication. *Simul. Gaming* **2020**, *51*, 632–652. [CrossRef]
33. Torres, M.; Macedo, J. Learning Sustainable Development with a New Simulation Game. *Simul. Gaming* **2000**, *31*, 119–126. [CrossRef]
34. Pereira, G.; Prada, R.; Paiva, A. Disaster prevention social awareness: The stop disasters! case study. In Proceedings of the 2014 6th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Vienna, Austria, 4–6 September 2014; IEEE: Piscataway, NJ, USA, 2014; pp. 1–8.
35. Soekarjo, M.; van Oostendorp, H. Measuring effectiveness of persuasive games using an informative control condition. *Int. J. Serious Games* **2015**, *2*, 37–56. [CrossRef]
36. Seibert, J.; Vis, M.J.P. Irrigania—A web-based game about sharing water resources. *Hydrol. Earth Syst. Sci.* **2012**, *16*, 2523–2530. [CrossRef]
37. Ertsen, M. Interactive comment on "Irrigania—A web-based game about sharing water resources" by J. Seibert and M.J.P. Vis. *Hydrol. Earth Syst. Sci. Discuss.* **2012**, *9*, C342–C345.
38. Perkiss, S.; Dean, B.A.; Gonzalez-Perez, M.A.; Heithaus, T.; Acosta, P.; Mills, R.; Gibbons, B.; Anastasiadis, S.; Bayerlein, L.; Jun, H.; et al. Learning experientially for corporate contribution to global sustainable development: International applications of the WikiRate project. In *The Palgrave Handbook of Learning and Teaching International Business and Management*; Springer: Berlin, Germany, 2019; pp. 697–720.
39. McPherson, S.; Anid, N.M.; Ashton, W.S.; Hurtado-Martín, M.; Khalili, N.; Panero, M. Pathways to Cleaner Production in the Americas II: Application of a competency model to experiential learning for sustainability education. *J. Clean. Prod.* **2016**, *135*, 907–918. [CrossRef]
40. Wendling, Z.; Emerson, J.; Esty, D.C.; Levy, M.A.; de Sherbinin, A. *Environmental Performance Index*; Yale University: New Haven, CT, USA; Columbia University: New Haven, CT, USA, 2018.
41. Available online: https://countryeconomy.com/indicators (accessed on 12 January 2020).
42. Chan, S.-L.; Wey, W.-M.; Chang, P.-H. Establishing Disaster Resilience Indicators for Tan-sui River Basin in Taiwan. *Soc. Indic. Res.* **2014**, *115*, 387–418. [CrossRef]
43. Kaufman, G.F.; Flanagan, M.; Belman, J. Playing the System: Comparing the Efficacy and Impact of Digital and Non-Digital Versions of a Collaborative Strategy Game. In Proceedings of the DiGRA/FDG '16, Dundee, UK, 1–6 August 2016.
44. Hsu, S.-H.; Wu, P.-H.; Huang, T.-C.; Jeng, Y.-L.; Huang, Y.-M. From traditional to digital: Factors to integrate traditional game-based learning into digital game-based learning environment. In Proceedings of the 2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, Banff, AB, Canada, 17–19 November 2008; IEEE: Piscataway, NJ, USA; pp. 83–89.
45. DeLeon, C. Rules in Computer Games Compared to Rules in Traditional Games. In Proceedings of the 2013 DiGRA Conference, Atlanta, GA, USA, 26–29 August 2013.
46. Chang, C.-C.; Warden, C.A.; Liang, C.; Lin, G.-Y. Effects of digital game-based learning on achievement, flow and overall cognitive load. *Australas. J. Educ. Technol.* **2018**, *34*, 155–167. [CrossRef]
47. Rebolledo-Mendez, G.; Avramides, K.; de Freitas, S.; Memarzia, K. Societal impact of a serious game on raising public awareness: The case of FloodSim. In Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games, New Orleans, LA, USA, 4–6 August 2009; pp. 15–22.
48. Wu, C.-J.; Chen, G.-D.; Huang, C.-W. Using digital board games for genuine communication in EFL classrooms. *Educ. Technol. Res. Dev.* **2014**, *62*, 209–226. [CrossRef]
49. Hermann, K. Field Theory and Working with Group Dynamics in Debriefing. *Simul. Gaming* **2015**, *46*, 209–220. [CrossRef]