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Using a Board Game to Teach about Sustainable Development

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Abstract: Examining and developing courses of education for sustainable development (ESD) is the goal of this study. Building on the theory of game-based learning, this study develops teaching strategies that employ board games for ESD. The design context of the board game, entitled "Be Blessed Taiwan", is situated in the dilemma between biological conservation and economic development. It incorporates four core systemic concepts: the economy, policies, society, and ecology. Students from two high schools played the game for 200 min and 400 min, respectively (100 min per week). The study collected complete pre-game and post-game data from 34 high school students, including the test of scientific concepts, and gameplay results. The research results indicate that students' test scores significantly increased after the gameplay with a medium effect size; specifically, a large effect on the dimension of biodiversity concepts and a medium effect on the dimension of biological conservation concepts. The analysis of students' gameplay results shows the difficulty for high-school students to achieve all four ESD goals.

Keywords: board game; board game teaching; education for sustainable development (ESD); board games for ESD

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1. Introduction

1.1. Education for Sustainable Development (ESD)

ESD promotes sustainable development through education processes all over the world. For the past 30 years, the ESD program has been valued by both governmental and non-governmental organizations [1]. In September 2015, the United Nations published The 2030 Agenda for Sustainable Development, and quality education is one of the major goals of this initiative (SDG4) [2]. Education is a key to addressing sustainable development issues [3,4]. With the ever-growing pace of economic development, the scope of issues related to this process is also becoming broader [5], leading to calls for more researchers and educators to participate in ESD [6]. ESD involves topics in social sciences, economics, environmental sciences, ecology, and other fields and emphasizes the approach of interdisciplinary learning [7]. The subjects of ESD courses are usually based on global events, such as climate change/global warming and biodiversity. In recent years, schools have gradually localized the ESD agenda and are increasingly focusing on sustainable development issues in students' hometowns [4]. The main purpose of ESD courses is to enable students to master knowledge and skills related to sustainable development to secure their employment and well-being, which is a long-term strategy for ingraining the concept of sustainable development [8,9] to ensure that the environment and social well-being is sustainable for both the current and future generations [10,11].

1.2. The Predicament and Issues Facing ESD

If schools rely on improving and disseminating scientific knowledge as the only means of teaching about human impact on the environment, people are unlikely to make behav-

ioral changes that support sustainable development. Literature reviews on the subject of ESD [8] indicate that, currently, ESD research has three directions: (1) teaching environmental and scientific knowledge, such as the water cycle and atmospheric circulation; (2) experiences in the natural environment; and (3) acting, participating, and making choices that support sustainable development. ESD courses should place equal emphasis on all three directions and integrate them into the formal curriculum [4,12]. ESD teaching should create opportunities for discussions, including the sharing of opposing opinions, so that learners with different standpoints can communicate, collaborate, and make choices. For instance, ESD courses in Samuelsson's study use the choice of buying organic eggs or conventional eggs to prompt students to discuss the contrast between humanity-oriented choices and economics-oriented choices [13].

In summary, ESD courses need to overcome these four bottlenecks. First, teachers overemphasize the learning of scientific or environmental knowledge, which leads to mere inculcation and memorization of information. Second, students rarely have opportunities to participate in discussions concerning sustainable development issues and then make their own choices. Next, during the teaching process, there are few opportunities for students to listen and think about conflicting standpoints. Lastly, the classroom setting rarely provides opportunities for students to make value choices or decide behavioral changes. Given these four bottlenecks, this study proposes a change to ESD teaching and addresses the subject of teaching in the form of policy topics. To avoid a situation in which teaching is the equivalent of shoving knowledge down students' throats, the focus should shift from teacher-centered to student-centered and allow students to gather learning materials themselves. Courses should create simulated scenarios that students can participate in and experience so that they have opportunities to apply ideas and make choices. Instructional activities can use roleplaying to present conflicts and competition between different standpoints and provide students with opportunities to communicate and collaborate in these conflicting situations. In general, such courses should create opportunities for students to deliberate on dilemmas, providing opportunities to make value judgments and behavioral choices.

1.3. Advantages of Teaching Using Board Games

The main goals that teachers hope to achieve by using board games in teaching are (1) increasing incentives for students to learn and reducing their resistance to learning [14–16]; (2) improving learning efficiency through frequent interactions and discussions among students [17–20]; (3) reducing the learning of complex system concepts and decreasing students' cognitive load [17,21,22]; (4) fostering new skills, such as critical thinking, problem-solving, teamwork, and communication and collaboration [23–26]. As a new type of game-based learning, the use of board games has many advantages and, therefore, is favored by many teachers [27].

First, a board game creates a small virtual society in which students can learn by trial and error and accumulate experiences in a virtual world. Based on the scenario around which the theme of the board game is designed, different events can be simulated. For instance, the theme of the Water Ark board game simulates the use and allocation of water resources [25]. The theme of the Crazy Water board game simulates residents' water use habits in their daily lives [28]. The Be Blessed Taiwan board game simulates Taiwan's economic development process [26]. With board games, teachers can let students participate in different scenarios according to the subject and goals of the class.

Second, board games are highly interactive. In these games, students can take the initiative to explore and exchange information with peers, thus promoting student-centered learning. With board games, participants play face to face, engaging in human-to-human interactions (interactions among players) and human-to-board game interactions (feedback provided to players by the board game's mechanisms). Students explore the board game's world and its mechanisms as beginners and, through the system's feedback and the

interactions among players, gradually become familiar with the rules and value systems of the board game [24–26,29].

The board game mechanism can foster competitive or collaborative relationships. Using different role plays, the groups engage in competitive or collaborative behavior. For instance, in the Water Ark board game, players represent the agriculture and livestock industry, the science and technology industry, government organizations, and civil groups. In their play, the four parties discuss and collaborate to determine the allocation of water resources. Similarly, the Be Blessed Taiwan board game is also based on different roles (for instance, farmers, hunters, businessmen, environmentalists, and the government). During the game, students make judgments and choices about the structure and direction of future economic development. Through collaboration and confrontation during role-play, students freely express their opinions, communicate, collaborate, and try to win peers over to complete the mission [28,29].

In addition, board games have high applicability and can be used to teach different subjects [30]. Teachers can design their own board games to achieve their teaching goals. The subjects of board games are broad and flexible and can include topics related to scientific, environmental, and social issues. Usually, the most suitable board games are those designed by teachers themselves.

In summary, this study contends that including board games in the design of ESD courses will help overcome the bottlenecks in teaching. Despite their benefits in helping with teaching, certain issues with board games need to be addressed. First, board games represent a new way of teaching and some teachers still do not know how to effectively employ them. Second, at present, most research focuses only on students' learning achievement and rarely analyzes the game-playing process. Third, there are only a few interdisciplinary board games that are suitable for ESD courses.

1.4. Research Questions

The purpose of this research is to use board games in the development of ESD courses and to perform a study of teaching using board games. The research does not propose that board game-based teaching can replace traditional teaching; rather, it offers new insights into and approaches to teaching to help fill the gaps in existing ESD courses. To this end, the study will focus on three questions:

(1) When the board game is used for ESD teaching, how does it affect students' learning performance?
(2) When the board game is used for ESD teaching, what are the students' playing process and the game results?
(3) How can the board game be used to enhance ESD teaching to achieve optimal teaching results?

2. Materials

This study uses the board game Be Blessed Taiwan [26,29]; building on the game, sustainable development concepts are introduced into the play process. The effects of the board game are evaluated in terms of four aspects—social development, economic growth, environmental protection, and animal survival—which mimic sustainable development indicators. The characteristics of the game enable students to freely communicate and interact with each other and explore the world of the game, making it a student-centered learning process wherein students think independently to develop their strategies, make final value judgments, and choose courses of action. This section will explain the thematic context, conceptual structure, rules and steps, and execution of the board game.

2.1. Thematic Context

Be Blessed Taiwan simulates Taiwan's economic development process. The teaching goal of this board game is to prompt students to think about how to achieve a balance between economic development and biological conservation and how to maintain peo-

ple's way of life in Taiwan in a way that realizes sustainable development goals. The background of the board game features scenes on the main island of Taiwan and the surrounding islands. Students play five roles: farmers and fishermen, businessmen, hunters, environmentalists, and government officers. Different roles have different capabilities: hunters and environmentalists are in opposite groups; and farmers and fishermen and businessmen are neutral. Students take turns in the role of government officer, and the student playing this role is the starting player. Each role is assigned a different mission in one of two major categories, economic development and environment conservation; in this way, players encounter confrontation and opportunities for collaboration. The following provides a brief explanation of each role's responsibilities (Figure 1):

- Farmers and fishermen: They are responsible for food production on the island and fishing in the sea to meet people's basic living needs.
- Businessmen: They are good at trade and can import economic products for sale or build business districts or factories.
- Hunters: They are good at hunting animals and trading fur for money; they can build business districts or factories.
- Environmentalists: They protect native species and guard against the introduction of exotic species.
- Government officers: They make development policies and build public infrastructure.

Figure 1. Role cards in the board game.

2.2. Conceptual Structure of the Game

Figure 2 shows the concepts covered in this board game. In addition to the social, economic, environmental, and ecological systems that are usually incorporated into studies of the environment, the concept of policy direction is added to better fit the key focus of sustainable development.

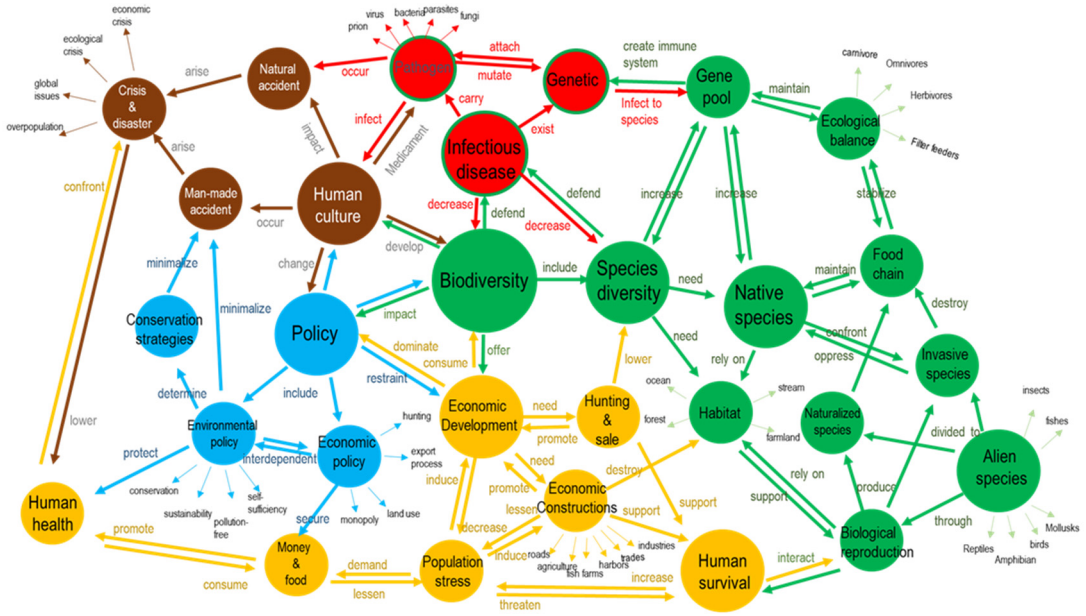


Figure 2. Concept map guiding the board game design.

2.2.1. The Ecological System

The ecological system is the key that centers on biodiversity and links other core systems together. It includes three key concepts: species diversity, genetic diversity, and ecosystem diversity. Species diversity is the main focus of Be Blessed Taiwan, and it incorporates such concepts as native species, alien and invasive species, naturalized species, and food chains. Genetic diversity and ecosystem diversity are supporting concepts, and they appear in the board game through the concepts of gene pool, reproduction, and habitat. A total of 21 native animals and 10 common alien species are included in the game. There is information about native species and invasive species on the animal cards, including their habitats, habits, characteristics, conservation level, and hazards. The animal cards enable students to learn about animals' characteristics and habits while playing the board game (Figure 3).

Figure 3. Examples of animal cards (**a**) native species: leopard cat (*Prionailurus bengalensis*); (**b**) alien species: red-eared slider (*Trachemys scripta elegans*).

2.2.2. The Social System

The social system represents the impacts of human culture. Related factors can be classified into three categories: natural events, man-made events, and infectious disease events (Figure 4). Human culture refers to the atmosphere of the play and the activities that take place when student groups play freely and communicate with each other. The occurrence of natural events, man-made events, and infectious disease events will affect students' thinking, judgment, and decisions while playing the board game. Natural events refer to climate-related disasters, including hurricanes and droughts. Man-made events refer to 19 types of disasters related to human activities that have occurred in Taiwan, such as the destruction of wildlife habitats, ocean pollution, and economic tsunamis. Infectious disease events are caused by fungi, bacteria, viruses, parasites, and prion proteins. Genetic differences among species determine whether immunity can be generated during infectious disease events. This design mimics genetic diversity to enable students to understand that species originating from small gene pools have a high risk of extinction.

Figure 4. Examples of social event cards: (**a**) natural events: severe typhoon; (**b**) man-made events: ocean pollution; (**c**) infectious disease events: virus as a pathogen.

2.2.3. The Economic System

In addition to the missions and challenges that are unique to each role, all of the roles share a common mission: maintaining people's lives on the island of Taiwan. As the number of rounds played increases, the population increases, which creates pressure on the population's ability to maintain its livelihood. Consequently, players must hunt animals and build business districts and factories to earn money and then invest the money in development or use it to buy food to maintain peoples' basic standard of living and health.

Different roles take different approaches to economic development. Farmers and fishermen, who specialize in agriculture and fishery, are mainly responsible for grain production. Hunters and businessmen, whose development modes are industries and commerce, can make large amounts of money to enhance economic development. Environmentalists, who promote a self-sustainable mode of development, aim to reduce environmental damage and hunting. The government is responsible for building public infrastructure (ports and roads) and enhancing transportation development. In the game, through discussions and strategic thinking, the players choose from the following seven types of economic facilities: farmland, fisheries, business districts, hunting huts, factories, ports, and roads.

2.2.4. The Policy System

The policy system includes 12 neutral topics that correspond to 24 policies and bills. Students can freely choose between economic development-oriented or environmentally friendly policies. All 12 neutral topics are historical issues that have occurred in Taiwan,

and they are simplified for the purpose of the game. Examples of these topics include farming vs. hunting and nuclear power vs. offshore wind power. The policy directions of these topics are all determined through student voting. A policy position voted for by students will affect the economic performance and completion rate of the goal and mission later in the game. Therefore, to win the game, students must discuss their policy choices within their group and communicate and collaborate with other groups.

2.3. Rules and Steps of the Board Game

The players of the Be Blessed Taiwan board game are divided into groups (3–4 students per group). Each group is assigned two missions: economic development (30 points) and environmentally friendly goals (30 points). The group that scores the most points (out of a total of 60 points) wins. Each group is responsible for maintaining their own people's lives, and deaths due to accidents or insufficient food will lead to the deduction of points. Extra points will be awarded to groups that maintain the lives of a large population. The board game has four phases (Figure 5): events, actions, policy decision-making, and settlement. A brief description of each phase is provided below.

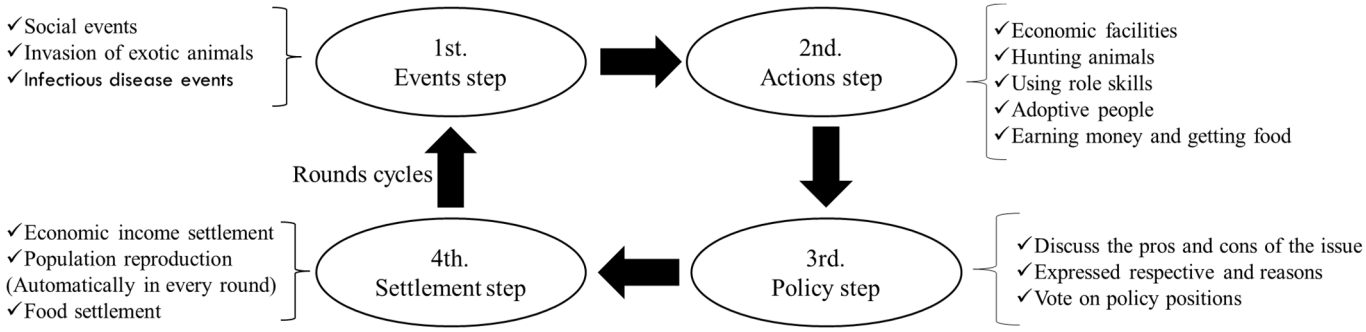


Figure 5. The steps of the board game (retrieved from Tsai et al. 2019).

2.3.1. Events Phase

During the events phase, the starting player tosses the dice to determine what and how many events will happen. There are three types of events: social events, invasion of exotic animals, and infectious disease events. When a social event happens, each group discusses how to deal with the event and mitigate the impact of the consequences. An invasion of exotic animals refers to alien species invading and reproducing in native habitats, and players must take measures to prevent invasion. When infectious disease events occur, genetic differences in individual animals will determine the extent of infection, thus, highlighting the importance of the gene pool.

2.3.2. Actions Phase

During the actions phase, each group of students discusses strategies and actions, such as hunting animals, building economic facilities, adding to the population (which may increase their action power), or using the skills of their role. Each group tries to face the challenge in a way that completes its mission and achieves its goals while maintaining people's lives. This is a key phase in which the students think about and make decisions that weigh economic development and biological conservation.

2.3.3. Policy Phase

During the policy phase, the group playing the role of the government selects the topics to be discussed. Within a given timeframe, each group discusses the topics, and a representative from each group presents the group's position and tries to persuade other groups. Finally, the groups vote on the policy decision. The implementation of economic development-oriented policies will promote animal hunting and the construction

of businesses and factories. The implementation of environmentally friendly policies will enhance biological conservation, agriculture development (on a small scale), and tourism industries. The policies implemented will change the rules of the game and the awards, and these rules will continue until the end of the game; therefore, students must conduct intergroup negotiations to arrive at the optimal solution.

2.3.4. Settlement Phase

The settlement phase is hosted by the game moderator (or teacher). During this phase, the economic income from each facility, the reproduction of exotic animals, and the amount of food are determined. Business districts and factories are economic facilities that generate income. The unit of measurement of exotic animals is the number of alien species; with each round of the game, two species populations are reproduced (with an upper limit of eight species). In each round, the human population also increases (reproduction is 25% of the total population). Players can feel the pressure of the increasing population. In terms of food, each unit of food can sustain one person; if the amount of food is not sufficient, the players need to buy more with their money. Without sufficient food or money, people will die, leading to point deductions for the group.

2.4. The Board Game Instruction

Board game-based ESD teaching is student-centered. The teacher, however, still plays a critical role in the process. As Figure 6 shows, ESD using board games does not mean that students just play by themselves. Before the game, the teacher must clearly inform students of the learning goals and the background and rules of the game. During the game, the teacher acts as the game host and adjudicator and does not participate in students' discussions and decision-making processes. During the game, students have plenty of opportunities to discuss and communicate. At each phase of the game, time is allotted for group discussions to ensure that students can fully express their personal standpoints. When the game is complete, the teacher facilitates discussions among the entire class and offers a review and evaluation of the game-playing process and results. The following questions may be asked: (1) During the game, what were some of the differences in standpoints between different roles? (2) What are some differences between the scenarios in the game and in real life? Please explain and give examples.

It can be seen from Figure 7 that ESD using board games provides students with more opportunities for discussion and communication. The teacher does not participate in the game; he or she only interprets the rules of the game and adjudicates the results. During the game, the teacher can provide supplementary information, clarify concepts and explain how the board game mimics the real world. For instance, the teacher could add that alien species are not necessarily invasive species; only when the number of animals from an alien species overwhelms the number of animals from native species is a species considered invasive.

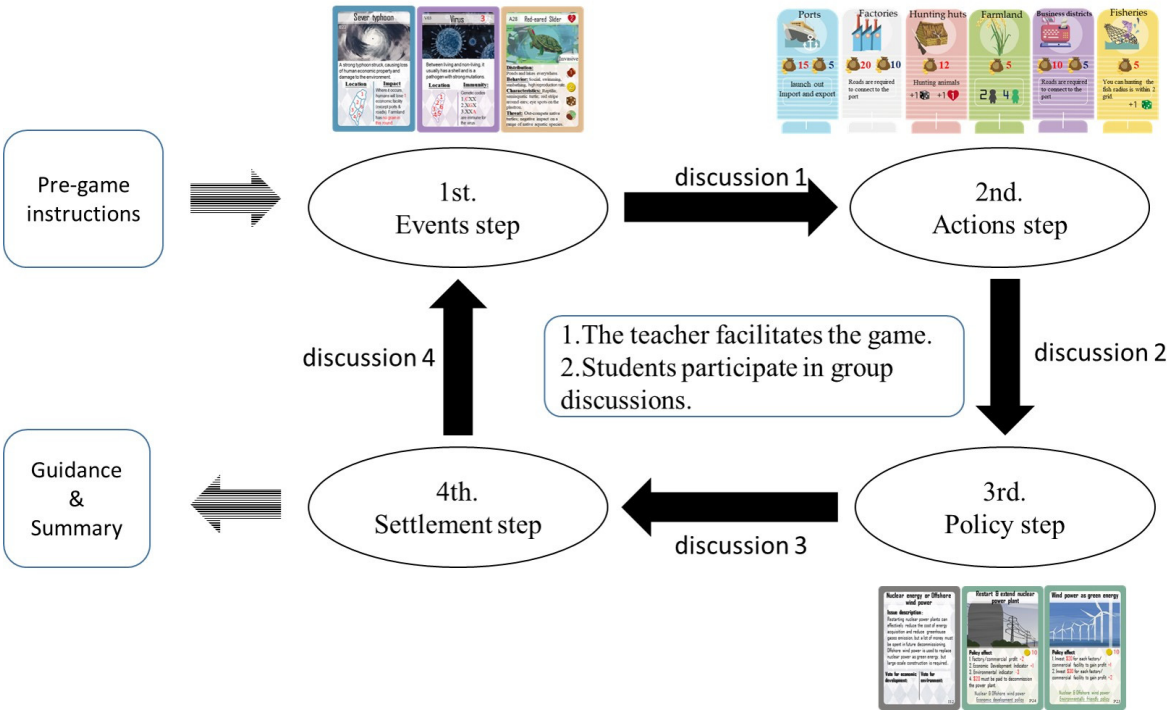


Figure 6. Execution process for board game-based ESD.

(**a**) (**b**)

Figure 7. The board game-based teaching process. (**a**) Teacher hosting the game. (**b**) Students participating in group discussions.

After the game is completed, the teacher provides an evaluation of the game results. The evaluation grades the game results based on four indicators: social development, economic development, environment, and animal survival (see Table 1). The four indicators correspond to the four major areas of sustainable development: social, economic, environmental, and ecological development (United Nations Development Programme, 2018). During the game-playing process, each group keeps a record of its performance. After these data are input into a spreadsheet, the grade is obtained. Economic development refers to the average total assets of all groups, and a higher amount in this indicator means better economic development performance. This indicator has three levels: social poverty, a moderately prosperous society, and a prosperous society. Social development is measured by the between-group wealth disparity. A larger wealth gap means greater social unrest. This indicator has three levels: social unrest, normal society, and stable society. Animal survival refers to the ratio of the number of native species to the number of exotic species.

When the number of native species decreases or there is an excess number of alien species, this ratio will decrease. To accentuate students' behavioral differences in biological conservation in the board game, this indicator has five levels: extinct, seriously threatened, chancy, adequate, and animal paradise. Environment refers to the ratio of the land area on the map that has been damaged by human construction activities to the land area at the beginning of the board game (before construction took place). Excessive construction activities that significantly damage habitats will reduce the grade on the environment indicator, which has five levels: serious destruction, obvious damage, slight damage, rational exploitation, and original state.

Table 1. Levels of development situations.

Indicators	Level 1	Level 2	Level 3	Level 4	Level 5
Economic development	social poverty 0~59	moderately prosperous society 60~89	prosperous society 90~100		
Social development	social unrest 0~39	normal society 40~79	stable society 80~100		
Animal survival	extinct 0~39	seriously threatened 40~59	chancy 60~79	adequate 80~89	animal paradise 90~100
Environment	serious destruction 0~29	obvious damage 30~59	slight damage 60~79	rational exploitation 80~89	original state 90~100

3. Methods

3.1. Research Context

For this study, both qualitative and quantitative data were collected. Board game-based teaching was carried out during elective courses or social group activities, and, therefore, the students were from different classes. Three board game teams from two high schools participated in the game; they were Team A, from School 1, and Team B and Team C, from School 2. The normal duration for board game-based teaching was 200 min (100 min each week). Team A from School 1 repeated the game, so the duration of play was extended to 400 min. The number of rounds played during each game is affected by student performance and the number of groups. Therefore, within the same time frame, the number of rounds each team plays may not be the same. Team A, from School 1, had five groups, and they played three rounds. Team B and Team C, from School 2, each had four groups, and they played four rounds in total.

3.2. Data Collection and Analysis

During the research, a complete set of the pre-game and post-game data from the 34 high-school students was collected. The data collected included the students' responses to the biological conservation concepts test, interviews, and the game-playing results. The biological conservation concepts test included 10 items designed to assess the students' conceptual understandings of biodiversity and biological conservation. The questions were compiled by the researchers and reviewed by two experts in science education and a school teacher to reach the content validity. The test lasted 25 min. During the board game play, the teacher recorded each group's results for each round of play.

For quantitative data, the research employed the paired test to analyze the pre-game and post-game scores in the biological conservation concepts test. The trend charts were used to analyze the game-playing process and the results of the game. The evaluation of game results included four indicators: economic development, social development, animal survival, and environment. Formulas were developed based on relevant Organisation for Economic Co-operation and Development (OECD) literature [31], and the formulas were

simplified in accordance with the actual parameters of the board game. The data recorded by the teacher during the game was input into Excel and converted into grade levels for each of the four indicators.

4. Results and Discussion

The results of this study are divided into three categories: the effect on students' conceptual learning, the game-playing performance and results. The following section presents an interpretation and discussion of each of these categories.

4.1. Effect on Students' Cognitive Learning

The results in Table 2 indicate that, overall, the students' learning performance improved significantly. The average score in the pre-game test was 4.2, while the post-game score was 5.20 (t = 3.74, p = 0.00). The effect size was moderate (Cohen's d = 0.69). The performance in the conception of biodiversity was significantly improved, with a pre-game average score of 2.23 and a post-game average score of 2.91 (t = 3.36, p = 0.00), representing a high effect size (Cohen's d = 0.70). This result is consistent with that of Tsai et al. (2019) [26], indicating that the board game can effectively improve students' conceptual learning performance. However, performance in the biological conservation concepts tests did not improve significantly, with a pre-game average score of 1.97 and a post-game average score of 2.29 (t = 1.93, p = 0.06), representing a small to moderate effect size (Cohen's d = 0.37).

This study found that although the board game can effectively improve students' conceptions of biodiversity, there is still room to improve their conceptions of biological conservation. In the game, the students usually had to maintain a living through hunting animals and maintaining competitive relationships. Consequently, it was difficult for them to accept the concept of biological conservation. However, the board game creates a situated learning environment to enhance students' awareness and concepts of sustainability issues [32,33]. Based on the findings, this study proposes that teachers could strengthen the review and discussion of various biological conservation plans after the game to improve students' strategic thinking skills when facing dilemmas.

Table 2. Assessment of scientific concepts related to biodiversity.

Assessment Dimensions (# of Items)	Pre-Game		Post-Game		*t*-Value	Effect Size (Cohen's *d*)	*p*-Value
	Mean	*SD*	*Mean*	*SD*			
Concepts of biodiversity (5)	2.23	0.92	2.91	1.02	3.36	0.70	0.00
Concepts of biological conservation (5)	1.97	0.86	2.29	0.83	1.93	0.37	0.06
Total (10)	4.20	1.45	5.20	1.43	3.74	0.69	0.00

4.2. The Results of Gameplay

The analysis of the students' performance and results was mainly based on four trend charts: the chart for each group's cumulative points for their mission, the chart for food production, the chart for the number of native species and alien species, and the chart for economic development.

Figure 8 shows the points the students earned towards their mission during each round of play. Each group had a different goal and challenge, and a maximum of 60 points could be earned toward the goal. The group with the most points was the winner. Figure 8a,b shows the point charts for Team A, from School 1, for their missions during their first and second plays, respectively. There were five groups in Team A, and they played three rounds during each play. There were four groups in both Team B and Team C, and they played four rounds. Between the first and second rounds, the students' performance improved significantly. Although the groups' missions were different during each play, their cumulative points indicated that when the students became familiar with the rules of

the board game, they were better at finding solutions to their tasks to increase their points. Figure 8c,d shows the score charts of Team B and Team C, from School 2, for their missions. The competition among the groups was intense. The groups' points did not always go up and, in some cases, even decreased due to interference from the other groups. For instance, the points of the fourth group from Team B, shown in Figure 8c, and the points of the second group from Team C, shown in Figure 8d declined. During the game, if groups could communicate and collaborate well and develop optimal strategies, their points would gradually increase. Inversely, excessive competition forced groups to dynamically adjust their action plans to avoid attacks or hindrances, which could lead to all sides losing points.

The points shown in Figure 8 indicate that students did learn to deliberate on and solve problems through playing the board game. During the game, the students adjusted their strategies during each round of play based on the feedback obtained through the games' built-in mechanisms and optimized their strategies. The students constantly adjusted their behavior during the game, which helped them achieve the learning goals of ESD.

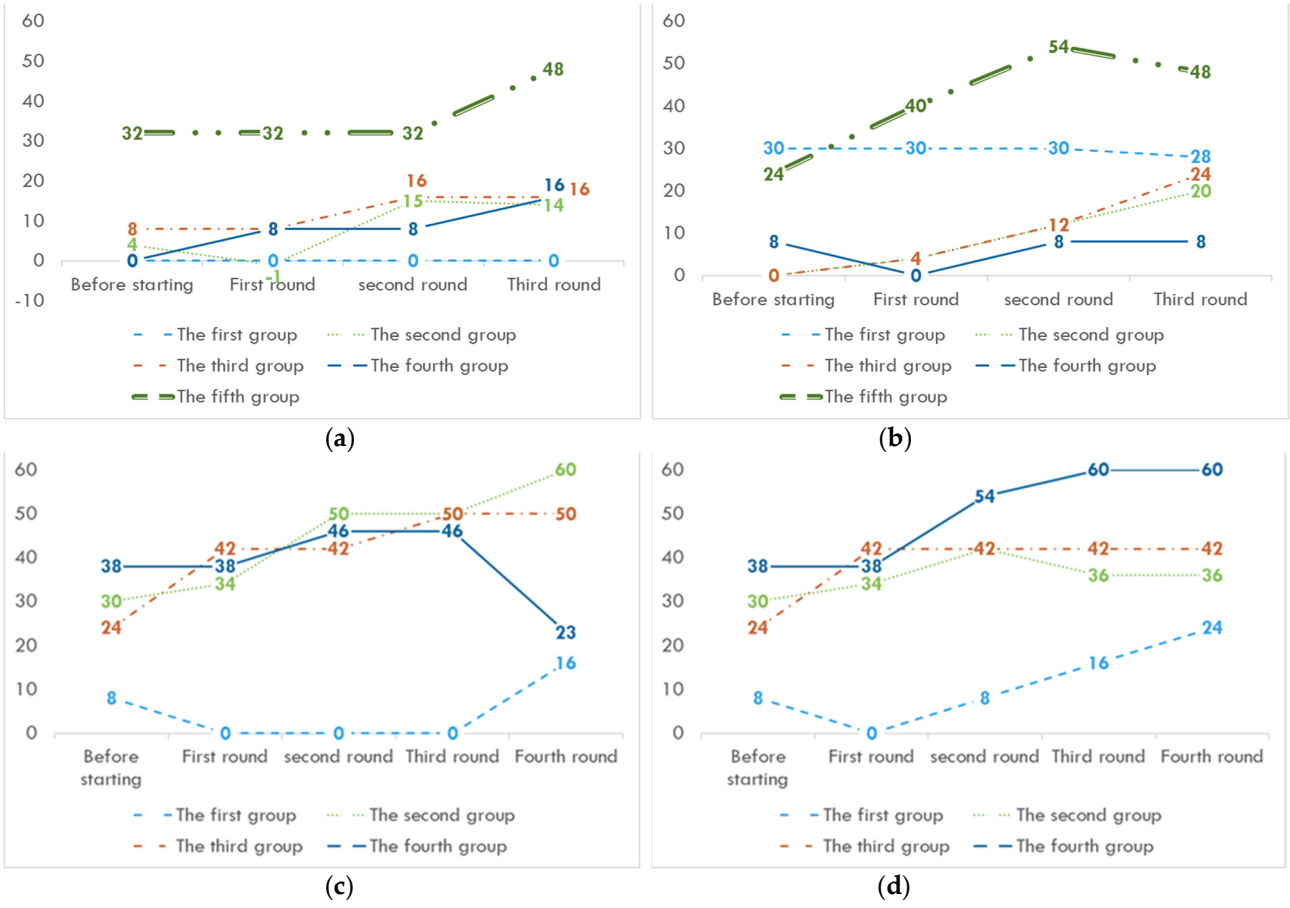


Figure 8. Group scores of (**a**) Team A during their first play, (**b**) Team A during their second play, (**c**) Team B, and (**d**) Team C.

Figure 9 is the food production chart, and it shows the population pressure that students faced when playing the game. In each round of the game, the population grows, and each group must earn sufficient money or produce sufficient food to meet the population's basic needs or people will die. Figure 9a,b shows that during Team A's second play, the total population grew, and the team faced higher population pressure than they did in the first game. The students, however, succeeded in securing sufficient money or food to keep the population alive. Figure 9c,d shows that Team B and Team C had different food strategies. Team C faced greater population pressure and needed more money or food to keep people alive, and the high population pressure created issues that affected

socioeconomic development. Team B chose to emphasize agriculture development, while Team C chose other approaches to economic development to keep the population alive.

Figure 9 presents each group's performance in food production as well as the social issues caused by population growth. The different strategies used by the students led to different social issues and economic development modes. In sustainable development, population pressure and maintaining basic life needs is an important topic. The board game reflects the real-life population issue and lets students experience it and find solutions.

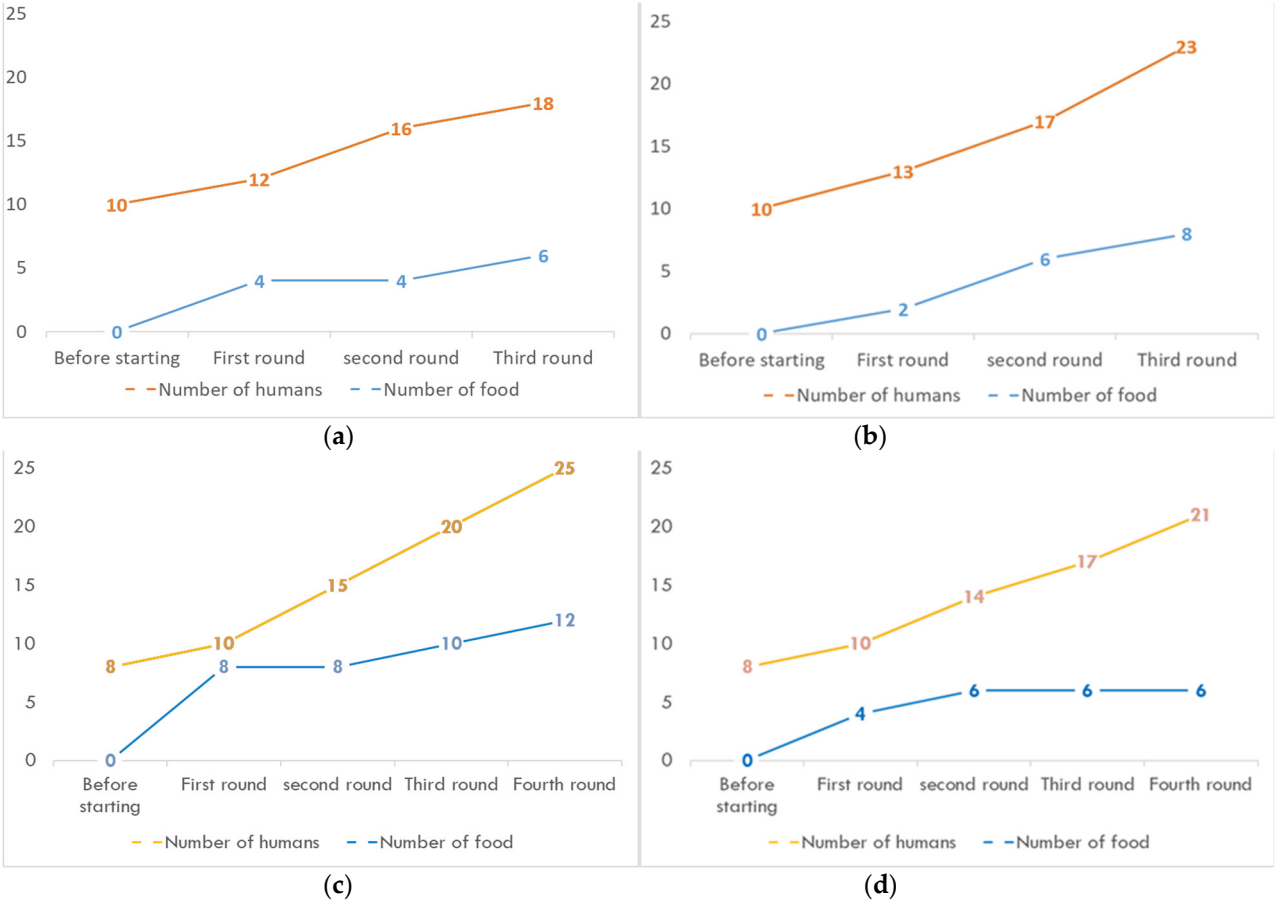


Figure 9. Trends in food production among the student groups: (**a**) results for Team A during the first game, (**b**) results for Team A during the second game, (**c**) results for Team B, and (**d**) results for Team C.

Figure 10 shows the trends in the number of native species and alien species; this is an indication of whether the students took biological conservation measures and preventive measures against alien species during the game. As can be seen in Figure 10a,b, Team A did not change its biological conservation strategies but continued to hunt native animals during the first and second games. However, Team A did well in preventing alien species, indicating that the students took defensive measures against these species. As shown in Figure 10c,d, Team B and Team C had distinctly different results in this indicator. Team B did well in both conserving native species and preventing alien species, and at the end of the game, the remaining number of native species was 92% of the original number of species. The number of alien species, shown in Figure 10c, indicates that Team B successfully prevented and suppressed the reproduction and growth of alien species and kept their numbers low. In contrast, Team C extensively hunted native animals and did not take preventive measures against alien species, allowing them to reproduce rampantly. With Team C's strategy, native animals would face serious survival pressure.

Using this board game for ESD teaching can lead students to realize the hazards of exotic, invasive species and then take actions. Although the students had different

approaches and achieved different results when playing the game, the simulated scenarios of the board game did quickly increase students' awareness of the problems facing biodiversity so that they could decide whether to take action. Teaching based on this board game can effectively create a sustainable development teaching scenario.

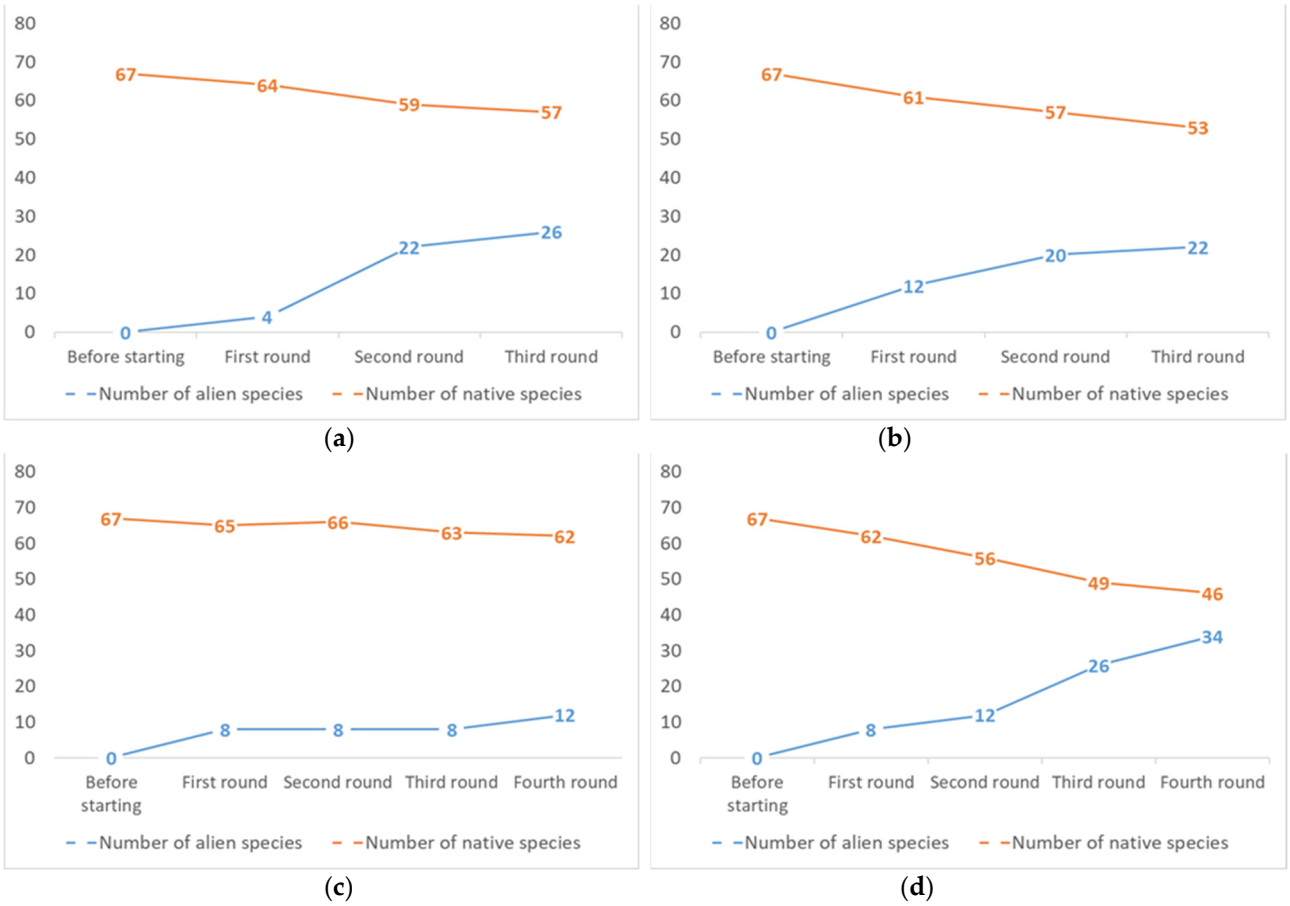


Figure 10. Trend of the number of native species vs. exotic species: (**a**) results for Team A during the first game, (**b**) results for Team A during the second game, (**c**) results for Team B, and (**d**) results for Team C.

Figure 11 shows the economic development performance that the students achieved while playing the board game. Figure 11a,b indicates that students in Team A performed better in economic development during their second game than during their first game. In Figure 11b, the curve of the total property of the human camp declined at first and then rapidly went up again, indicating that Team A made inappropriate economic development decisions at first, leading to the decline of the total property curve, but they later adjusted their strategies and achieved rapid economic growth. As can be seen in Figure 11c,d, Team B and Team C differed in their economic development performance. For Team B, the curve for the total property of the human camp maintained a trend of fast growth throughout the game, indicating that the students on this team used good economic development strategies to maintain the positive growth. Figure 11d indicates that although Team C also maintained positive growth at first, due to excessive population pressure and lack of food, the overall economy contracted during the fourth round of the game. This exercise helps students become aware of the importance of food self-sufficiency. An excessively low self-sufficiency rate will not meet the food requirements of the continuously growing population and is not conducive to sustainable economic development.

The board game successfully simulates issues that may be encountered during economic development. Students need to choose appropriate economic development strategies during the game; otherwise, they will face the issues of economic decline and insufficient

food for the population. The integration of the board game into the ESD course enabled students to experience simulations of various scenarios and policies in economic development and witness the importance of communicating and collaborating with peers when taking actions.

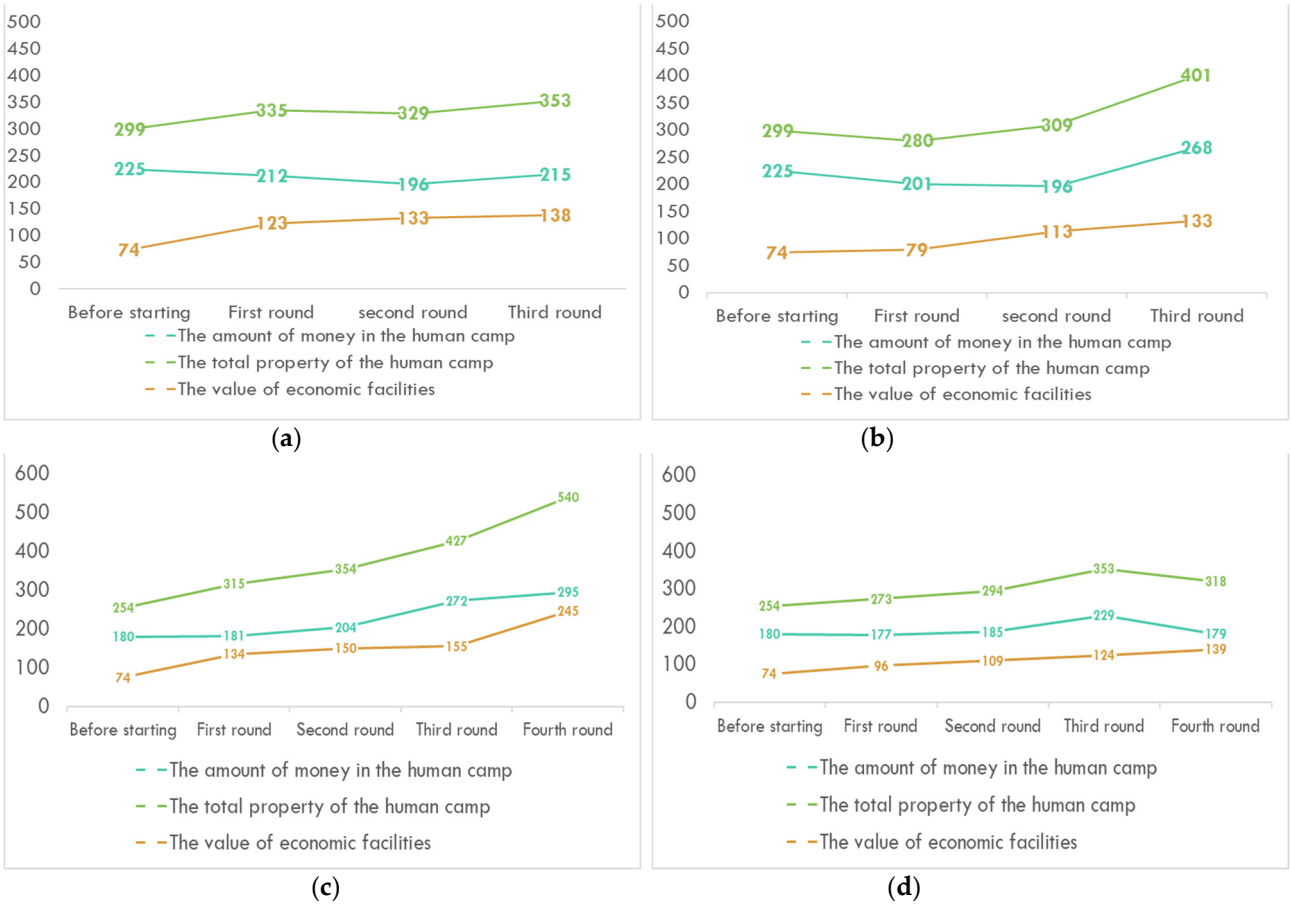


Figure 11. Economic development trend: (**a**) results for Team A during the first game, (**b**) results for Team A during the second game, (**c**) results for Team B, (**d**) results for Team C.

Many educators have suggested using simulated board games to teach ESD. Such games make use of game mechanisms to help students deepen the experience and cultivate decision-making and critical thinking [34,35]. Table 3 presents the policy choices made by Team A during their two games. During each round of the game, the group that acted as the government selected the topic of the discussion. The policy directions chosen by Team A changed in each of the games. For the three rounds of the first game, the students voted for an economic development-oriented policy twice. In the second game, the students voted for an environment-oriented policy twice. Issue card #4 (economic supremacy or environmental sustainability) was drawn during both plays, and the students' choice changed from the economic development-oriented policy to the environment-oriented policy. This exercise showed the students' thought process and the change in their standpoint when they faced the same topic.

Table 4 indicates that the policy directions of Team B and Team C differed. In the four rounds played by Team B, the policy choice determined by group discussions and voting was economic development-oriented. Team C did not show an evident preference in policy direction. Based on group votes, they chose an economic development-oriented policy twice and an environment-oriented policy twice. During play, the government's decision will change the rules of the game and affect the economic development results. For instance, the costs of building economic facilities and revenue will change in each

round. Figure 11c,d indicates that Team B maintained economic growth throughout the game, while Team C experienced an economic decline during the last round. This is an indication that a team's topic selections and policy decisions will lead to different economic development results. As Tables 3 and 4 indicate, the game mechanism sets students to play different roles and respond to different policies and events. They learned to communicate with peers within-group and coordinate between groups, which is a key competence to be cultivated in an ESD course. The gameplay context also allows them to transfer positions and thinking perspectives in dealing with sustainability issues to foster a better decision-making ability [24,32,35].

Table 3. Policy choices of Team A.

	Team A-1	**Team A-2**
First round	#4 Economic supremacy vs. Environmental sustainability	#6 Alien species vs. Native species
Voting results	Economic development oriented	Economic development oriented
Second round	#2 Industrial orientation vs. Agricultural orientation	#4 Economic supremacy vs. Environmental sustainability
Voting results	Environment oriented	Environment oriented
Third round	#1 Farming vs. Hunting	#2 Industrial orientation vs. Agricultural orientation
Voting results	Economic development oriented	Environment oriented

Table 4. Policy choices of Team B and Team C.

	Team B	**Team C**
First round	#1 Farming vs. Hunting	#4 Economic supremacy vs. Environmental sustainability
Voting results	Economic development oriented	Economic development oriented
Second round	#3 Expand production capacity vs. Service industry	#2 Industrial orientation vs. Agricultural orientation
Voting results	Economic development oriented	Environment oriented
Third round	#6 Alien species vs. Native species	#7 Land development vs. Animal protection
Voting results	Environment oriented	Economic development oriented
Fourth round	#5 Large-scale constructions or Embracing Nature	#6 Alien species vs. Native species
Voting results	Economic development oriented	Environment oriented

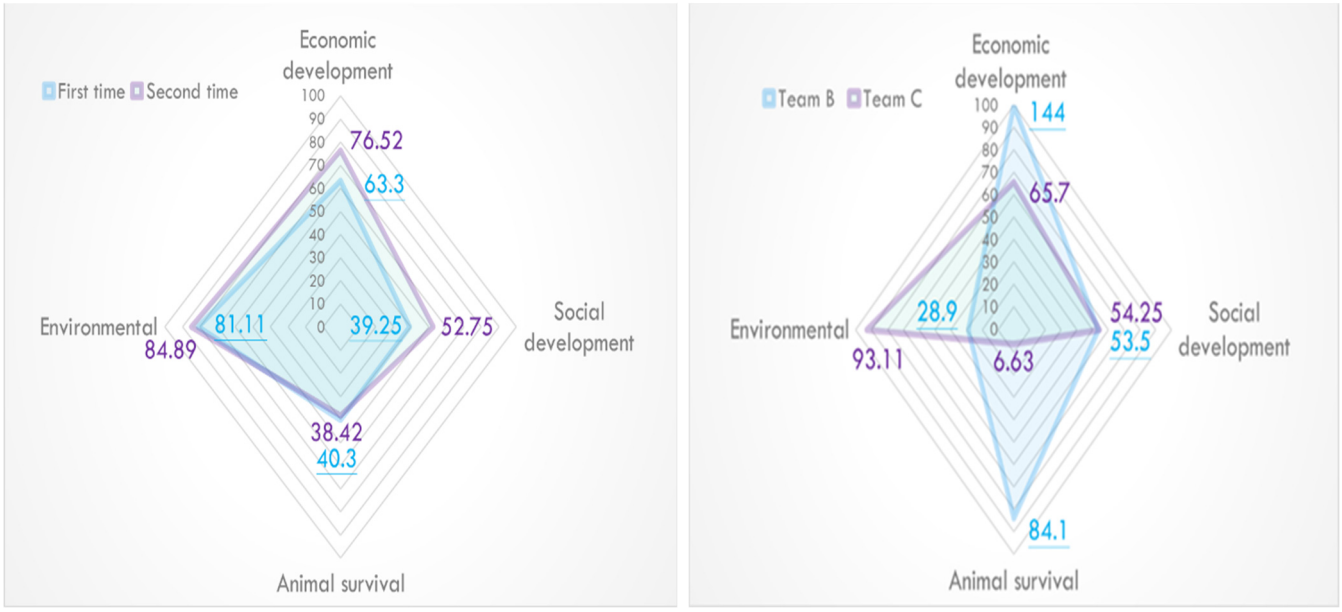
The board game enables students to realize the effects of policies on development in various areas. The establishment of a policy system enables students to experience a simulation of the process of selecting topics and making policy decisions and understand the impact of these decisions. This exercise prompts students to perform more rational analyses of the policy development process, make more objective choices, and choose the most reasonable solutions based on the actual situation. Through simulation-based training, ESD courses enable students to effectively develop policies and bear their consequences.

In accordance with the converted results for the four sustainable development indicators (social development, economic development, environment, and animal survival) for the Be Blessed Taiwan board game, the optimal development mode should have the following grades for the four indicators: economic development at the moderately prosperous society level (60–89), social development at the normal society level (40–79), animal survival at the chancy level (60–79), and environment at the slight damage level (60–79). Figure 12 presents the overall evaluation results for Team A, Team B, and Team C. Figure 12a shows that Team A did not meet the benchmark on the indicators of social development and animal survival during their first game; they reached the social unrest and seriously threatened levels in these two indicators, respectively. Although the team did not do well in these two indicators during their second game, either, their performance in social development improved from social unrest to the normal society level, indicating that Team A made certain adjustments to their strategies with regard to social development. In addition, Team A improved their economic development and environment levels. During the second game,

Team A reached the ideal level in the indicators of economic development, environment, and social development, once again showing that when students play the game a second time, they are able to think and make decisions more comprehensively and systematically.

Figure 12b shows the results for the four sustainable development indicators for Team B and Team C. Team B reached the requirements for three indicators: economic development (prosperous society level), social development (normal society level), and animal survival (adequate level). This result indicates that Team B did not use effective strategies, although it achieved excellent performance in economic development. Team C also met the benchmarks for three indicators: economic development (moderately prosperous society level); social development (normal society level), and environment (original state). This result indicates that Team C performed excellently on the environmental side but did not do well on the conservation of native species. This occurred mainly because Team C chose the primary economic development mode, in which hunting animals constituted the major source of revenue, and did not take measures to prevent the invasion of alien species.

Using the four indicators for sustainable development allowed a comprehensive evaluation of the students' performance during the board game. The high school students that participated in this study were not able to meet the benchmark for all four target areas of sustainable development. The Be Blessed Taiwan board game reflects the reality of development and is complex and challenging due to its interdisciplinary nature. Using board games for ESD courses can effectively help students think in a more comprehensive and systematic manner rather than focusing solely on learning scientific knowledge. Through the simulated environment of a board game, the high-school students achieved ideal results in the learning of sustainable development concepts.



(**a**) (**b**)

Figure 12. Student performance in sustainable development indicators after the game. (**a**) Results for Team A, from School 1, during two games, (**b**) results for Team B and Team C, from School 2.

5. Conclusions

The research results indicate that using the Be Blessed Taiwan board game for ESD has a good learning effect. The board game can help students improve their understanding of biodiversity and conservation concepts and enhance their ability to make policy decisions. The game successfully enables students to experience biological conservation and economic development and fosters their interdisciplinary and systems thinking as well as building life skills such as communications and team collaboration.

While playing the board game, high-school students were willing to actively address the issues and continuously develop new strategies and make new decisions to achieve their group's goal. The Be Blessed Taiwan board game has four core systemic concepts, which correspond to the sustainable development goals. Therefore, using the board game in teaching can fulfill teaching requirements in multiple fields instead of leading students to focus only on learning conceptual knowledge. From the game results, it can be seen that during the game, students could make decisions and change their behavior and were willing to express their personal views and discuss them with peers. The results of the board game play indicate that high school students could not achieve balanced development across all four sustainable development indicators (economic development, social development, animal survival, and environment). This means that it is difficult for students to change their beliefs and values through short-term playing or learning and that they still used life experience as their criterion for making judgments. However, the changes that students exhibited as they actively adjusted their developmental strategies and behaviors during the game indicate that the students were able to independently think about and reflect on their decisions and make independent judgments.

This study suggests that when using the board game for ESD teaching, the teacher should serve as a facilitator rather than playing along with the students and that the teacher should not interfere with play and should only neutrally adjudicate. The use of board games for teaching represents a game-based learning method. Teachers should capitalize on the frequent interactions that occur during board game play to help students learn during ESD courses and meet the educational goals, such as affective aspects, values, problem-solving, and decision-making. Teaching using board games does not mean that students just play by themselves. The teacher should clarify concepts, provide supplementary information, and lead discussions and summaries during and after the game. In the future, board games with different themes should be developed so that different scenarios can be simulated to assist with ESD teaching.

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References

1. Lélé, S.M. Sustainable development: A critical review. *World Dev.* **1991**, *19*, 607–621. [CrossRef]
2. Sachs, J.; Schmidt-Traub, G.; Kroll, C.; Durand-Delacre, D.; Teksoz, K. SDG Index and Dashboards Report. 2017. Available online: http://www.sdgindex.org/assets/files/2017/2017-SDGIndex-and-Dashboards-Report--regions.pdf (accessed on 6 July 2017).
3. McKeown, R.; Hopkins, C.A.; Rizi, R.; Chrystalbridge, M. *Education for Sustainable Development Toolkit*; Energy, Environment and Resources Center, University of Tennessee: Knoxville, TN, USA, 2002.
4. Hedefalk, M.; Almqvist, J.; Östman, L. Education for sustainable development in early childhood education: A review of the research literature. *Environ. Educ. Res.* **2015**, *21*, 975–990. [CrossRef]
5. Marten, G.G. *Human Ecology: Basic Concepts for Sustainable Development*; Earthscan: Gateshead, UK, 2001.
6. Jickling, B.; Wals, A.E. Debating education for sustainable development 20 years after Rio: A conversation between Bob Jickling and Arjen Wals. *J. Educ. Sustain. Dev.* **2012**, *6*, 49–57. [CrossRef]

7. United Nations Development Programme. Sustainable Development Goals. 2018. Available online: http://www.undp.org/content/undp/en/home/sustainable-development-goals.html (accessed on 24 October 2019).
8. Nousheen, A.; Zai, S.A.Y.; Waseem, M.; Khan, S.A. Education for sustainable development (ESD): Effects of sustainability education on pre-service teachers' attitude towards sustainable development (SD). *J. Clean. Prod.* **2020**, *250*, 119537. [CrossRef]
9. Merritt, E.; Hale, A.; Archambault, L. Changes in pre-service teachers' values, sense of agency, motivation and consumption practices: A case study of an education for sustainability course. *Sustainability* **2019**, *11*, 155. [CrossRef]
10. Brundtland, G.H. World Commission on Environment and Development. In *Our Common Future*; Hagerhall, B., Ed.; Prisma: Stockholm, Sweden, 1988.
11. Kemp, S.; Bellingham, L.; Longhurst, J. *Education for Sustainable Development: Guidance for UK Higher Education Providers*; The Quality Assurance Agency for Higher Education (QAA); Higher Education Academy (HEA): York, UK, 2014.
12. Lee, J.C.K.; Ma, W.H.T. Early childhood environmental education: A Hong Kong example. *Appl. Environ. Educ. Commun.* **2006**, *5*, 83–94. [CrossRef]
13. Samuelsson, I.P. Why we should begin early with ESD: The role of early childhood education. *Int. J. Early Child.* **2011**, *43*, 103–118. [CrossRef]
14. Enyedy, N.; Danish, J.A.; DeLiema, D. Constructing liminal blends in a collaborative augmented-reality learning environment. *Int. J. Comp.-Support. Collab. Learn.* **2015**, *10*, 7–34. [CrossRef]
15. Lauren, H.; Lutz, C.; Wallon, R.C.; Hug, B. Integrating the dimensions of NGSS within a collaborative board game about honey bees. *Am. Biol. Teach.* **2016**, *78*, 755–763. [CrossRef]
16. Law, V.; Chen, C.H. Promoting science learning in game-based learning with question prompts and feedback. *Comput. Educ.* **2016**, *103*, 134–143. [CrossRef]
17. Anupam, A.; Gupta, R.; Naeemi, A.; JafariNaimi, N. Particle in a box: An experiential environment for learning introductory quantum mechanics. *IEEE Trans. Educ.* **2018**, *61*, 29–37. [CrossRef]
18. Casanoves, M.; Salvadó, Z.; González, Á.; Valls, C.; Novo, M.T. Learning genetics through a scientific inquiry game. *J. Biol. Educ.* **2017**, *51*, 99–106. [CrossRef]
19. Dietrich, N. Escape classroom: The Leblanc process—An educational "Escape Game". *J. Chem. Educ.* **2018**, *95*, 996–999. [CrossRef]
20. Whitton, N.; Langan, M. Fun and games in higher education: An analysis of UK student perspectives. *Teach. High Educ.* **2019**, *24*, 1000–1013. [CrossRef]
21. Sampson, C.; Linard, E.; Garcia-Chance, L. Life's a beach: Using role-playing scenarios to facilitate water quality studies. *Am. Biol. Teach.* **2018**, *80*, 353–358. [CrossRef]
22. Stokes, L.C.; Selin, N.E. The mercury game: Evaluating a negotiation simulation that teaches students about science-policy interactions. *J. Environ. Stud. Sci.* **2016**, *6*, 597–605. [CrossRef]
23. Goon, M. Peacekeeping the game. *Int. Stud. Perspect.* **2011**, *12*, 250–272. [CrossRef]
24. Eisenack, K. A climate change board game for interdisciplinary communication and education. *Simul. Gaming* **2013**, *44*, 328–348. [CrossRef]
25. Cheng, P.-H.; Yeh, T.K.; Tsai, J.C.; Lin, C.R.; Chang, C.Y. Development of an issue-situation-based board game: A systemic learning environment for water resource adaptation education. *Sustainability* **2019**, *11*, 1341. [CrossRef]
26. Tsai, J.C.; Cheng, P.H.; Liu, S.Y.; Chang, C.Y. Using board games to teach socioscientific issues on biological conservation and economic development in Taiwan. *J. Balt. Sci. Educ.* **2019**, *18*, 634–645. [CrossRef]
27. Wen, J.M.; Lin, C.; Liu, E.Z.F. Integrating educational board game in Chinese learning environment to enhance students' learning performance and flow experience. *Int. J. Online Pedagog. Course Des.* **2019**, *9*, 31–43. [CrossRef]
28. Cheng, P.H.; Tsai, J.C.; Chen, S.Y.; Chang, C.Y. Learning transfer to daily habit: The design and effectiveness of water resources board Game. *J. Environ. Educ. Res.* **2020**, *16*, 1–36.
29. Tsai, J.C.; Chan, K.C.; Chen, P.C.; Liu, S.Y.; Chang, C.Y. Design and teaching application of the biodiversity scientific board Game for elementary school students. *Sci. Educ. Mon.* **2020**, *430*, 7–32. (In Chinese)
30. Cheng, P.H.; Lee, W.S.; Chang, C.Y. Modeling science board games. *Sci. Educ. Mon.* **2019**, *419*, 20–38. (In Chinese)
31. Lamichhane, S.; Eğilmez, G.; Gedik, R.; Bhutta, M.K.S.; Erenay, B. Benchmarking OECD countries' sustainable development performance: A goal-specific principal component analysis approach. *J. Clean. Prod.* **2020**, *287*, 125040. [CrossRef]
32. Ozenc, S.G. Introduction of a strategic board game that is aimed at educating children about sustainable development goals of United Nations. *Eur. J. Soc. Sci. Educ. Res.* **2020**, *7*, 49–57.
33. Miller, J.L.; Wentzel, M.T.; Clark, J.H.; Hurst, G.A. Green machine: A card game introducing students to systems thinking in green chemistry by strategizing the creation of a recycling plant. *J. Chem. Educ.* **2019**, *96*, 3006–3013. [CrossRef]
34. Gatti, L.; Ulrich, M.; Seele, P. Education for sustainable development through business simulation games: An exploratory study of sustainability gamification and its effects on students' learning outcomes. *J. Clean. Prod.* **2019**, *207*, 667–678. [CrossRef]
35. Corridoni, T.; Kocher, U.; Reggiani, L. Education for sustainable development and game theory. *Perspect. Sci.* **2014**, *2*, 22–45. [CrossRef]