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USING BOARD GAMES TO TEACH SOCIOSCIENTIFIC ISSUES ON BIOLOGICAL CONSERVATION AND ECONOMIC DEVELOPMENT IN TAIWAN

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Abstract. *This research uses board games as teaching material to develop students' decision-making ability and basic scientific literacy and to foster students' value for nature and social caring by working with socioscientific issues. The board game structure contains four perspective systems: ecological, economic, cultural, and political. In the game processing, students must handle, consider, and understand the different role players' positions and face different missions that involve socioeconomic and environmental conflicts. When making any decisions, students affect the follow-up game behaviors and develop tendencies. The board game instruction was field-tested with 38 high-school students from two different high schools. Students played the board game for a total of 200 minutes. Students' scientific conceptions concerning biodiversity (closed-ended) and perspectives on socioscientific issues (open-ended) were assessed before and after the board game lesson. The results showed that students in both high schools significantly increased their understanding of biodiversity concepts, with a high level of effect size (Cohen's d equal to 1.40 and 1.06, respectively, for the two schools). In the semistructured interviews, the interviewed students were able to reflect on the value of animals and provide various opinions about animal conservation and economic development.*
Keywords: *board game, decision making, descriptive research, game base learning, socioscientific issue.*

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Introduction

Motivations for Using Board Games in Teaching

Board games have been accepted and utilized by many science teachers in recent years. They have many advantages because they do not rely on expensive high-tech equipment, are widely applicable and flexible, improve students' learning motivation, make complicated concepts more acceptable, cultivate students' new abilities, and increase learning efficiency (Berland & Lee, 2011; Eisenack, 2013; Goon, 2011; Yusof, Radzi, Din, & Khalid, 2016). Game-based learning is a useful teaching method that integrates different scientific topics and social events into teaching (Divjak & Tomić, 2011; Eisenack, 2013; Goon, 2011; Yusof, Radzi, Din, & Khalid, 2016). In the past, the didactic instruction or topic discussion methods could not keep learners interested or focused for long (Li & Tsai, 2013). The use of board games employs a kind of game-based teaching method. Some scholars believe that the use of game-based learning leads to effective learning results by enhancing students' experiences and improving their positive feelings regarding the learning process (Gee, 2007). Game-based learning has the potential to become a mainstream teaching method in future science teaching (Berland & Lee, 2011; Eisenack, 2013; Goon, 2011; New Media Consortium, 2005, 2006). In fact, research in the science education field has shown that students often have high motivation to learn the subjects while immersed in game playing (Eisenack, 2013; Goon, 2011; Yusof, Radzi, Din, & Khalid, 2016). In board games, there are three major elements, including game rules, game play, and game narratives (Ang, Avni, & Zaphiris, 2008). Through appropriate game mechanisms and design, we can simulate various issues, scenarios, and challenges with various difficulty levels and real experiences (Garris, Ahlers, & Driskell, 2002) to achieve the best learning perception flow (Csikszentmihalyi, 2014). In sum, evidence in the literature suggests that using a board game can

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strengthen students' interaction, communication, negotiation, self-learning, and learning by playing (Bayir, 2014; Berland, & Lee, 2011; Eisenack, 2013; Farmer, & Schuman, 2016; Goon, 2011; Peppler, Danish, & Phelps, 2013; Yusof, Radzi, Din, & Khalid, 2016).

Teaching of Socioscientific Issues

STSE (science, technology, society, environment) is an educational approach advocated by many scholars (Liu, Lee, & Tsai, 2007; Pedretti, 1999; Zeidler, Sadler, Simmons, & Howes, 2005) that involves students in dealing with scientific issues from social, cultural, political, and environmental perspectives. Socio-scientific issues are characterized by public concern, significance, inconclusiveness, complication, and diversity, and they are closely related to life, personal values, and feelings (Pedretti, 2003; Liu et al., 2007). Biodiversity is not merely a scientific concept but also a large and complex environmental issue. The National Academy for Educational Research (2016, 2017) listed the four systems of ecology, culture, economy, and policy as the important contents of sustainable environment education. School education has long overemphasized scientific concepts and has neglected an overall teaching approach that covers sociology, economics, and humanities (Pedretti, 2003, Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008, Pedretti, & Bellomo, 2013; Liang, 2015). Moreover, teachers have tended to adopt direct instruction at all times in classrooms. Outdoor activities for investigating environmental issues are susceptible to problems such as conflicts in curriculum arrangements, difficulties in implementation, and teachers' inadequate motivation (Liang, 2015). Therefore, developing indoor instruction on socioscientific issues that are not confined to the discussion of printed texts and data or the learning of scientific concepts is valuable for informing science and environmental education. Such instruction should provide students with opportunities to express their opinions based on learned scientific concepts and help them to make informed decision on controversial issues (Caro et al., 2003; Cheng et al., 2019; Halim & Saat, 2017).

Researchers argued that the traditional STS education fails to maintain students' continuous attention and input because its teaching implementation neglects the distance of these STS issues from students' daily life experience (Zeidler et al., 2005). If socioscientific issues are taught in the traditional argument form, not all students are able to participate in the decision-making process on the issues. They can only collect and analyze data or discuss positions and conclusions. This way of teaching might not motivate all students to apply scientific knowledge to deal with the problems in their daily life (Liu et al., 2007). The main purpose of socioscientific teaching is to help students learn and become interested in science through science-related issues, as well as to enhance students' thinking about personal scientific and environmental ethics in society. Socioscientific teaching also aims to promote students' scientific literacy, such as critical thinking, decision-making, communication, and negotiation (Liu et al., 2007; Zeidler et al., 2005). Therefore, the model of socioscientific teaching serves as the main component in the design of the board game in this study. Argumentative dialogs in the decision-making process are not common in conventional science learning but are an important theme in Taiwan's new curriculum guidelines (Taiwan's Ministry of Education, 2018). According to the guidelines, learning performance indicators for scientific literacy include decision- making, critical thinking, reasoning, and problem-solving. Therefore, this research adopted biodiversity-related environmental issue (Hudha, Amin, Sumitro & Akbar, 2018) as the context of a board game to develop indoor instruction to foster students' scientific literacy.

Theoretical Foundation and Content Framework of the Board Game

Theories of Board Game Teaching

The role of board games is not only to play for fun; they can also serve as learning material. Through appropriate learning models and concept systems attached to instructional objectives, students will be motivated to learn relevant knowledge and to solve problems when they are engaged in playing board games. By using scientific board games in the teaching of socioscientific issues, we can create simulated environments and scenarios and match them with role playing. The game process can be designed to cultivate students' abilities in communication and cooperation and to encourage them to express their own ideas about the issues. There is no comprehensive learning theory about board games, but the one presented here is in line with the characteristics of game-based learning. According to Garris et al. (2002), the input-process-outcome game model (Figure 1) can be used to understand the learning model of scientific board game. The inputs of the board games include teaching contents,

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game goals, game mechanisms, and situations. In terms of the process, game goals or challenges are used as motivations to involve students in the game process, which requires students' reaction, thinking, judgment, and systemic feedback. Finally, through the teachers' guidance and summary, the students achieve learning outcomes.

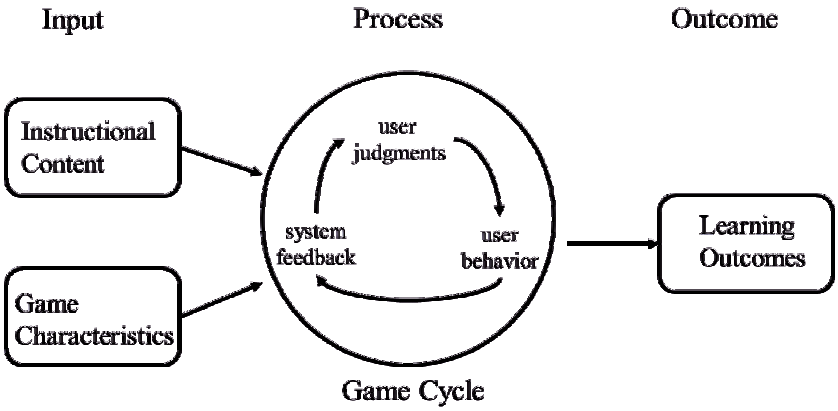

Figure 1. Garris's input-process-outcome game model.

The Context for the Use of Board Games for Socioscientific Issues

The board game used in this research is a science board game called "Be Blessed Taiwan." The content of the game is related to socioscientific issues, and its theme involves the tension between biodiversity conservation and economic development in Taiwan. According to the Ministry of Education of Taiwan, education on biological conservation should cover four aspects, including the environment, economy, culture, and policy. These aspects comprehensively cover the scientific concepts and environmental conservation information in this sector. Therefore, the scientific board game used in this study also includes these four aspects. In terms of the biological aspect, the content of the game covers scientific conceptions concerning biodiversity, such as ecological diversity, species diversity, genetic diversity, invasion of alien species, and viral infection. In terms of the economic aspect, it mainly covers animal hunting and the construction of man-made infrastructure. Humans can hunt animals and trade them for money. Construction can be realized by building six different kinds of facilities, including farmlands, fisheries, commerce facilities, industrial facilities, hunting houses, and roads. Although the construction of farmlands and fisheries supports basic purpose of human livelihood, there are still potential problems, such as overfishing and excessive land reclamation. Currently, commerce and factories are the main economic activities in Taiwan. Commercial districts can bring in high, cost-effective economic income, while factories can earn large amounts of cash income through export and processing. However, both will damage the environment and human health. Ports and roads are indispensable elements for economic development. Roads connect all parts of the country so that goods can be transported for profit. Ports can export goods overseas to earn foreign exchange and support offshore fishing operations. In terms of the culture aspect, taking social events in Taiwan as cases, students must think about problems such as industrial pollution, ships hitting the rocks, the greenhouse effect, and the financial crisis and attempt to make adjustments or find solutions for them. In terms of the political aspect, students are asked to make choices on dilemmas. Students must take a position and come up with reasons based on their judgment of the conditions in the game. They must communicate, negotiate, and reach consensus with one another to formulate policies and bills that will affect the overall development trend of the follow-up games.

Research Questions

To change the conventional socioscientific teaching methods that use printed information and data for discussion, this research intended to use scientific board games as the teaching approach for debates, discussion, and decision-making to cultivate students' scientific skills.

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A. Does the application of board games in the teaching of socioscientific issues help to improve students' understanding of scientific concepts of biodiversity?
B. Does the application of board games in the teaching of socioscientific issues improve students' decision-making on biological conservation and economic development issues?

Research Methodology

Descriptions of the Board Game

The scientific board game "Be Blessed Taiwan" is a simulation game that simulates the early stage of the land of Taiwan, with a rich diversity of native species and ancestors migrating to this land. Students act in two different camps in the board game, the animal camp and the human camp. The actions of the human camp aim to manage the land, such as hunting, agriculture, industry or commercial trade. The goal of the animal camp is to help as many native species as possible survive to the end. In the research setting reported here, there were three groups in each camp with 4~5 students in each group. This board game also requires intragroup cooperation and intergroup competition. For example, the greater the number of native species the animal group can maintain the higher their points. The victory goal of the human camp is to reach the requirements on a randomly picked economic target card and an environmentally friendly card to earn task points. Therefore, the group of players must constantly make choices and engage in discussion during the game process to balance economic development and environmental conservation to obtain the highest task points. The board game is open ended and students have no standard protocol to find answers or to reach the goals. Students work in groups to develop their strategies and to decide whether economic development and biological conservation should be conflicting or balanced. The process of the board game is divided into four stages (Figure 2).

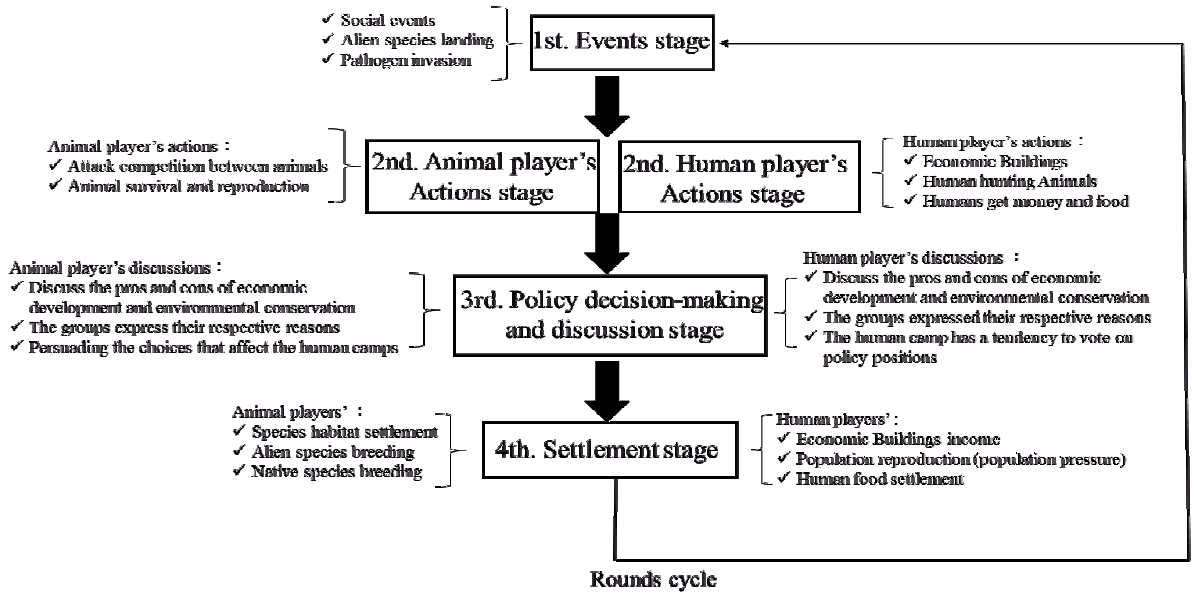

Figure 2. Stage descriptions for the board game "Be Blessed Taiwan".

1. Events stage: There are three kinds of events: social events, alien species landings events, and pathogen invasion events. The type of event and the number of occurrences are randomly decided by rolling dice. Figure 3(a) shows the social event cards. Social event cards include information such as the event narrative, the disaster impact and how to remedy and resolve the event (students can choose to solve it or have the disaster sustained). Figure 3(b) shows the information on the invasive species cards, including distribution location, intrusion mode, animal characteristics, and hazard impact. The invasive species chosen in this game are those with ability of rapid reproduction that threaten the survival of

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the native species. Figure 3(c) displays a pathogen card. It is composed of a pathogen narrative, an occurrence position and the type of genes that are immune. The design of the pathogen invasion events is intended to make students understand the importance of genetic diversity. In playing the game, students realize that when a pathogen invasion occurs in one place, all of the animals in the area will be infected except for those with the immune gene sequence shown on the pathogen cards. They should be able to observe that the greater the genetic diversity, the greater the species' opportunity to survive.

Figure 3. Example cards, (a) social event card; (b) invasive species card; and (c) pathogen cards.

2. Action stage: The players are divided into the animal camp and the human camp. Each group can choose to perform any two of the following actions. Human players can choose to trade, hunt animals, and move. Animal players can choose actions such as attack, prey, and reproduce. Before the actions stage, students can discuss and decide what actions they want to take. When students achieve consensus, the group's speaker expresses their actions, and the group's executor performs the actions (Figure 4).

Figure 4. Students playing in the actions stage (photo taken by Pin Sheng Li).

3. Policy making and discussion stage: In this stage, every group has a discussion about the topics of the issues in every round. Figure 5(a) is an example of the issues cards. Students can choose from 12 issue topics. On the card, there is a narrative to introduce the different position

https://doi.org/10.33225/jbse/19.18.634

statements for economic development and environmentally friendly policies. All topics are related to the status of Taiwan's past, present, and future. Figure 5(b) shows on environmentally friendly policy, which usually presents a smaller and slower economic benefit, self-sufficiency or less environmental damage. Figure 5(c) displays the statement on economic development policy, which usually focuses on a faster and larger economic benefit but high environmental damage.

The starting player in the human camp presides over the discussion of the dilemma topics. The advantages and disadvantages of taking different positions on an issue are described and then debated by all groups. After the discussion, every group's speaker presents their position and reasons. Figure 6 shows the students attempting to convince other groups to support their position. The animal camp can also express opinions at this stage, but they do not have voting rights. Finally, the human groups cast a vote to decide the policy stance, which can support either ecological conservation or economic development. The game rules are changed by following the new policy stance in terms of their vote.

Figure 5. (a) An issue card; (b) an example of environmental policy; (c) an example of economic policy.

Figure 6. Students present their position and reasons in the policy-making and discussion stage (photo taken by Pin Sheng Li).

https://doi.org/10.33225/jbse/19.18.634

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4. Settlement stage: Various settlements are performed. For the animal camp, there are settlements of species habitat, alien species breeding, and native species breeding. For the human camp, there are settlements of economic income, population reproduction, and human foods. Each round is played in a sequence of four stages in approximately 40 minutes, and a total of five rounds are played (200 minutes).

When students finish the board game, the instructor presents a trend chart. For example, Figure 7(a) shows the line chart of human economic development trends. It shows three kinds of trend information, including the amount of money, property, and facilities in every round. The instructor uses these trend charts to elicit what happened in the playing process. In this case, something happened in the second round due to a curve drop. Figure 7 (b) shows the trend chart for the comparison of animal quantities, including information on the numbers of exotic and native species in every round. This trend chart shows that the exotic species threatened and oppressed native species. By reading the information on the trend charts, the instructor draws students' attention to the impact of their behavior decisions on the resulting numbers of animals. Students can reflect by discussing the board game process.

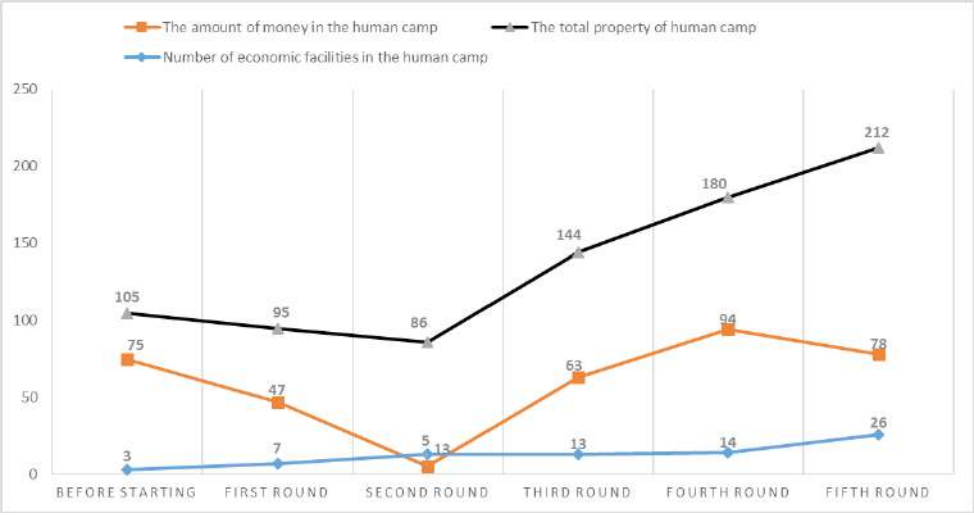

Figure 7(a). Human economic development trends.

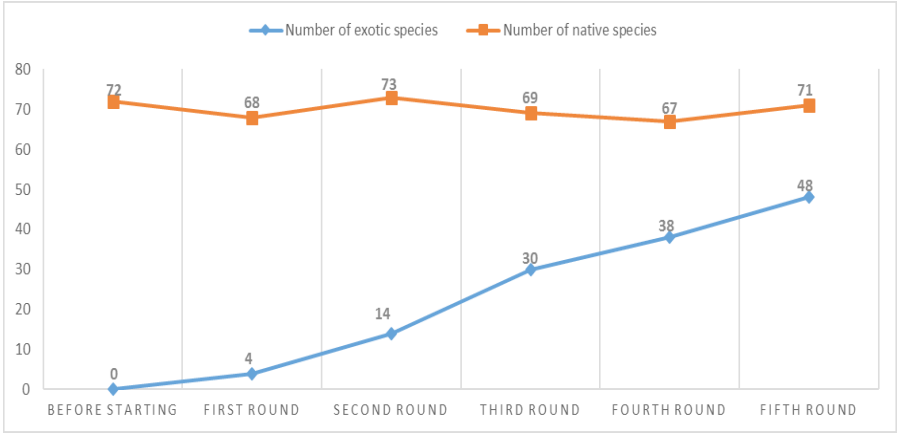

Figure 7(b). Animal quantity comparison trends.

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Participants

This board game teaching was field-tested with 38 high-school students from two different high schools. One of the schools was a high school and the other was a vocational high school. The students were between 15 and 16 years old. Students spent 200 minutes (four class periods) to complete playing the board game.

Data Collection

A questionnaire was compiled to assess students' scientific concepts of biodiversity and perspectives on socioscientific issues before and after the board game lesson. Ten multiple-choice items were selected from the assessment database of Taiwan's EPA and modified for this research. Among the items, four were designed to identify students' general concepts about the meaning of biodiversity, invasive species, and human-nature relationships, while six were aimed at the local situation. For example, one item asked students to identify which animal species was not on the protected list, another item was to identify whether students understood that Taiwan's high biodiversity is due to its climate and topography. In addition the closed-ended question items, we designed two open-ended questions to elicit students' ideas about whether biodiversity is related to daily life and whether there is any conflict between biological conservation and economic development. The content validity of the question items was checked by three science educators and two biology professors. The pre-test and post-test took 50 minutes each. After the course was completed, 10 students were interviewed on a voluntary basis. The interviews took a total of 60 minutes.

Research Results

Comparisons of the Pre- and Post-tests

In Table 1, school1 indicates students from a vocational high school in which the biology course is elective. School2 is a regular high school in which students had completed a biology course. Both chools are located in a metropolitan area. Table 1 presents the comparisons and pre- and post-test scores of the 10 closed-ended items. A Shapiro-Wilk test was performed to confirm the normal distribution of the data (p=.483 and .659, respectively). The results showed that both schools have made significant progress in biodiversity concepts, with a large effect size (the Cohen's d of the two schools was 1.40 and 1.06, respectively).

Table 1. Assessment of the scientific concepts of biodiversity.

School	*N*	Mean-pre(SD)	Mean-post(SD)	*t* value	*p*-value	Cohen's *d*
School1	21	4.81(1.43)	6.71(1.27)	4.52	<.001	1.40
School2	17	6.05(1.67)	7.52(1.00)	3.12	.007	1.06

Through the design and arrangement of the board game, students not only increased their knowledge of biodiversity but also were able to take action in the game process using the principles of these scientific concepts. In the case of a viral invasion, not all creatures will be infected depending on their genetic codes. The higher the genetic diversity of a species is, the less likely it is to become extinct. After finishing the game, the instructor summarized the game results and organized discussions so that students could clarify alternative concepts and reflect on their actions in the game process.

A preliminary analysis of students' responses to the open-ended questions regarding their perspectives on biological conservation and economic development did not show differences (Table 2). In the analysis of qualitative data, students' flexibility (the number of answers) and fluency (the number of description perspectives) were scored. Based on the criteria we created to score students' responses, the score of the students from schooll significantly decreased, with a median negative effect size. The post-test score of the school2 students was slightly higher than pre-test score but did not reach statistical significance.

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Table 2. Assessment of perspectives on socioscientific issues (open-ended test).

School	*N*	Mean-pre(SD)	Mean-post(SD)	*t*-value	*p*-value	Cohen's *d*
School1	21	5.5(2.2)	4.55(1.50)	-2.33	.031	-0.5
School2	17	4.65(1.32)	4.82(1.63)	.436	.668	0.11

Results of Semistructured Interview

After the completion of the board game lesson, 10 students participated in semistructured interviews on their thoughts and feelings about using scientific board games to learn the socio-scientific issues. One student expressed his in-depth reflection on the context of the board game as follows:

> S1: Human beings and animals coexist in Taiwan! "Be Blessed Taiwan" divides human beings and animals into two camps in the discussion, which shows it is not just human beings who run Taiwan; animals can also interfere with or help humans. Aren't there also alien species? Some animals will attack alien species. Because in the end, if human beings do not want (abandon) those alien species, they might invade the native species in Taiwan.

After playing the game, students' attitudes towards the relationship between human beings and animals could be divided into two types: 1) humans and animals are interdependent, and 2) humans only consume and utilize natural resources. We further asked aout the importance of the existence of animals with no economic value. Is it necessary for humans to protect them?

> S2: I think the relationship between human beings and animals is interdependent. You might think some animals are not important; however, nature is interlocked. Maybe if some animals disappear, a whole chain effect will break out, and things will happen one after another. So every animal is valuable! Because you don't know what will happen if even one of them disappears.
>
> S3: If I do not hurt you, you won't harm me! As for why we should protect animals, it's because some animals may only exist in this place or a few places in the world. Some animals might only exist in Taiwan. If they disappear, our offspring will have no idea about them. So, we should protect them.
>
> Teacher: So you believe because they are rare and precious, their existence is valuable even if they are not useful to human beings?
>
> S3: Yes!
>
> S4: An animal that does not have economic value. It is of no economic value only to human beings. However, it may be the king in a certain area…
>
> Teacher: That is to say, we should not define the value of the animal from human beings' point of view.
>
> S4: Yes! It also depends on the role of the animal in that area.
>
> Teacher: In other words, we should not think from a human-centered perspective but treat the environment as a whole.

All of the interviewed students agreed that human beings should protect animals that have no economic value for three reasons: 1) the existence of a creature is valuable in itself; 2) due to the food-chain relationship, its impacts on the future ecosystem and the potential risks cannot be accurately predicted, so it should be protected; and 3) judgment should not be made from a human-centered perspective; instead, the environment and ecology as a whole should also be taken into consideration.

https://doi.org/10.33225/jbse/19.18.634

Discussion

The purpose of this research was to help improve students' scientific concepts of biodiversity by using a socioscientific issues board game. The use of board games in teaching socioscientific issues has achieved good results, especially regarding the scientific concepts of biodiversity. Our results show that the scientific board game facilitated students' learning of the concepts of biodiversity, which is also in line with the conclusions of other scholars that board game learning can achieve conceptual learning (Berland & Lee, 2011; Eisenack, 2013; Goon, 2011; Yusof et al., 2016).

According to the interviews, students provided positive feedback on learning the scientific concepts of biodiversity by playing the board game. We also observed that students could interact with their peers to build empathy on the topics and increase their awareness of related issues during the game. In line with Berland and Lee (2011) and Eisenack (2013), this research suggests that the interactions among players and in the game context serve as important factors in learning by playing.

There are only a few existing board games that address socioscientific issues. For example, Eisenack(2013) designed the "Keep Cool on Climate Change" board game, Goon (2011) developed a socioscientific board game called "Peacekeeping the Game", and Yusof, Radzi, Din, and Khalid (2016) developed the socioscientific board game "Project Manager". Socioscientific board games can motivate students to make judgements on issues of science and society.

In contrast to previous teaching methods for socioscientific issues, scientific board games can help students pay more attention to, reflect on, and participate in the entire simulation process. Although most students have high acceptance of using scientific board games in learning about socioscientific issues, according to the video records of the observations, a few students showed no interest in playing. This result suggests that there is still room for improvement in using board games, such as the slow pace of the games and the varying degree of students' participation.

The results of the assessment of perspectives on socioscientific issues (open-ended test) did not show significant improvement, which is consistent with the conclusion of Hsieh, Liu, and Chen (2013). One school's score did improve, but the score of the other significantly declined. This study found that most Taiwanese students do not like writing and were unwilling to express their complete opinions in written responses to the open-ended question. Therefore, we conducted semi-structured interviews to confirm students' experience and perceptions regarding the value of biological conservation. As shown by the interview results, students learned about the relationship between human beings and animals, as well as the importance of ecological conservation by playing the scientific board game. Moreover, they could independently propose to protect ecology from a nonhuman-centered point of view.

Hsieh et al. (2013) believed that it is difficult to find appropriate assessment tools for students' qualitative thoughts about socioscientific issues. They recommend the use of other assessment approaches to obtain more direct evidence and information. Qualitative assessment tools should be further developed and improved to meet the evaluation needs of such innovative teaching materials. Summarizing and discussing the experience of students in the games could significantly improve students' responses and attention. This approach is also in line with the results of many studies showing that board games can stimulate students' learning motivations (Berland & Lee, 2011; Eisenack, 2013; Goon, 2011; Yusof et al., 2016).

Conclusions and Suggestions

Socioscientific board games can provide students with more opportunities for interpersonal interactions and scientific literacy development. In addition, the field-test results suggest that socioscientific board games are good teaching material for scientific topics, such as the issue of biodiversity conservation in this case. This research strongly endorses that board games featuring other socioscientific themes should be developed to improve students' learning motivation and scientific literacy. Future research regarding how to motivate teachers to use socioscientific board games in the science classroom may be merit. Monitoring students' decision-making process on different socioscientific themes through board game playing could contribute to the research field of socioscientific issues education.

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