Design Ideas for an Issue-Situation-Based Board Game Involving Multirole Scenarios

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Abstract: In learning based on socio-scientific issues, teachers primarily use role playing in situation learning to promote students' knowledge and responsibility and to teach them how to reach a consensus in multirole scenarios. However, if participants only engage with the material from the perspective of having one role, they will ignore comprehensive information on said issue. Therefore, the roles students play during multirole situational learning lead to diversity biases in learning results. To help participants enhance their competencies related to issues and eliminate learning gaps, we developed an issue-based board game named Water Ark based on the following four design ideas: multirole simulation, reflective goal, systemic situation, and interactions of society. The results indicated that after playing the game, participants' knowledge and responsibility regarding water resource adaptation improved significantly. Furthermore, the findings revealed that the gap between the learning outcomes of participants with different roles in the game was not statistically significant, except in terms of students' personal willingness to act. Thus, these design ideas could improve the utility of board games for learning about socio-scientific issues with multirole scenarios.

Keywords: socio-scientific issue; issue-situation-based board game; multirole situational learning; reflective goal

1. Introduction

1.1. Learning about Socio-Scientific Issues

With the development of science and technology, the public often encounters issues that encompass social dilemmas with conceptual or technological links to science in daily life. Scientific and societal content are core aspects of these issues and interact with each other. These issues are referred to as socio-scientific issues (SSIs) [1–3]. Examples of SSIs from previous studies are as follows: (1) System at issue is that SSI involves various relationships between the contents of science and society, which is considered a complex system; (2) public and society, because SSIs affect the livelihood and wellbeing of the public, optimal solutions to solve any problems that arise have attracted considerable interest; (3) multiple opinions, because SSIs are related to the public's quality of life, public opinion should be considered when deciding on the approach to solving problems; (4) Openness, because society

is a complex system and the public holds various opinions, problems are usually open ended with multiple plausible solutions [4].

The aim of SSI learning is to develop practices and dispositions for students to actively participate in society, such as content knowledge, interest and motivation, higher-order thinking, and a community of practice [5]. Hence, this study focused on three basic competencies as follows: (1) The knowledge of the scientific community and society about SSIs. These aspects interact with each other and have numerous correlated factors. If students understand the relationships between those factors, they can develop a more comprehensive understanding of the subject [6,7]. (2) Personal responsibility and willingness to act on SSIs, i.e., personal responsibility affects the public's willingness to actively address SSIs [8,9]. However, members of the public are generally unaware that they have a responsibility to help solve such issues, making it difficult to promote a positive disposition towards SSIs [10–12]. (3) The personal action for public benefits in SSI, because addressing SSIs has public benefits, members of the public who are primarily concerned with personal benefits at the expense of public benefits can have negative reactions to these topics [10,13]. Therefore, improving students' personal actions for public benefits is essential for the study of SSIs [14].

Teachers primarily use simulated experiences in situation learning to promote students' knowledge of and attitude towards SSI [15,16]. Fox and Loope (2018) developed educational tools based on role playing to teach students about issues related to invasive species with complex factors, including biology, geography, sociology, and politics [17]. Furthermore, to enhance young people's interest and engagement in public issues, Chawla and Cushing (2007) suggested that teachers allow students to share their experiences to enable others to imagine and imitate the experiences from the sharer's perspective using experimental studies and reviews [18]. Moreover, Arslan, Moseley, and Cigdemoglu (2011) developed and field tested the educational game EnviroPoly. They reported that it had the potential to motivate students and increase their enjoyment of learning about pertinent issues [19]. These studies used methods with role-playing learning characteristics that were seemingly effective for learning about SSIs.

1.2. Role Playing in Learning and Its Possible Disadvantages

Role playing is a learning technique that provides an understanding of a topic through examining its role in real-world issues. It simulates an environment where participants can experience having a certain identity related to a topic. This motivates participants to engage with a task and express their opinions on related topics. This technique can help clarify the systems involved in an issue and the thought process behind actions taken, which leads to reflection on potential solutions to the situation [20,21]. Role playing allows participants to attain knowledge in a different manner and improve their approach to problem solving in a real-world context. This technique promotes a change of perspective, which is necessary to promote problem-solving behavior [14].

The aim of learning about SSIs is to solve public problems. Because one of the properties of SSI-based learning is openness, various opinions are held on approaches to solving problems. For solving methods to be effective and consistent, it is vital that the participants reach a consensus on them [1,22]. Therefore, in some situated learning cases, educators assigned students to different groups in which each student played a role in addressing a specific issue to teach them how to reach a consensus [16,23]. However, the different roles assigned can lead to differences in the students' learning outcomes. Participants have to choose a role to play, and thus engage in learning through the perspective that they have adopted, and they usually care about themselves and no other. If students play different roles to other students in the same course, the content obtained is also different, which can lead to a diversity bias in learning results when using multirole scenarios [14,21,24]. In addition, in SSI, it is important that people pay attention to other people's topics and multiple perspectives when they make decisions. Therefore, we investigated this aspect of SSI learning.

1.3. Board Games for Multirole Scenarios

Board games can be an appropriate tool for improving SSI situated learning and multirole scenarios. Board games place players in a face-to-face situation in which they must use accessories and follow the rules to achieve the game's goal. These characteristics have led to board games being serious games for learning. The serious game is a game where education is the primary goal, and it involves pedagogical activities for imparting knowledge or skill. Hence, a serious game needs to present the learning content and be a blended learning experience that seamlessly integrates enjoyment and learning [25–27]. Serious games are usually designed with features to promote cognitive learning, such as aligning the goals for play and goals for learning, creating encouragement from social and gaming support for assisting in goal attainment, and constructing feedback mechanisms for monitoring and revising cognition [28–32].

Previous studies have reported that certain features of board games can create an autonomous learning environment which encourages role playing for experiential learning, engagement in goal-orientated motivation, acquiring knowledge of procedural rules and mechanisms, and social learning through player interaction [33–36] used in SSI-based learning. Juan and Chao (2015) designed a board game named "Green Building" which teaches students about the relationships between building, industry, and the environment through game feedback mechanisms [37]. Mostowfi, Mamaghani, and Khorramar (2016) developed an educational board game to teach players about recycling. Achieving the game's recycling goals led to increased knowledge and self-efficacy outcomes without teachers or others present to manage game activity [38]. Another simulated role-playing board game, named "Keep Cool", teaches players that some activities of industries result in an increase in greenhouse gases and climate change [39].

These findings suggest that board games improve students' understanding of SSIs and their attitudes towards SSI-based learning. However, these studies focus on learning specific knowledge and improving motivation for the issue. If we wish to confirm the characteristics of SSI-based environments (e.g., system at issue, public and society, multiple opinions, and openness), to promote participants' performance (e.g., knowledge, responsibility, and action on public), and to encourage participants to pay attention to others in SSI-based education, this study assumes that a board game should be developed with the following specific features:

> **Multirole simulation:** Multirole simulation makes each participant play a role different from others. It simulates multiple opinions to present integrated topics on SSIs in the game. Simulating various roles in the same game allows participants to understand the involvement of their own and others' roles in the topic. They would also learn how to reach a consensus on SSIs [23].
>
> **Systemic situation:** After setting a multirole simulation, we have to design a systemic situation which constructs the science- and society-based systems of SSIs using two features of the board game, namely procedural rules and feedback mechanisms. A systemic situation simulates the systems of the issue into gaming process and the relationships between the affected factors into mechanisms. A complex concept can be simplified and integrated through the design of appropriate rules. Therefore, a systemic situation improves the participants' knowledge and attitude towards the main contents in an issue by playing the game [24]. The systemic situation would contribute to systemic learning, and then the reflective goal would improve participants' metacognition in learning.
>
> **Reflective goal:** The reflective goal is modified from the goal orientation of the game. The aim of the reflective goal is to engage participants' personal metacognition to pay attention to the topics, including their own and others'. The goal is comprised of hidden key factors for game continuance, which are affected by the roles played by the participants, such as public benefits, organizational support, and resource maintenance. If a participant is unaware of these key factors and ignores others' development when they made decisions, everyone loses the game. Losing the game can cause participants to identify the hidden key factors and to modify their behaviors

together. Therefore, if learners want to achieve their objectives, they need to employ public thinking and utilize mutually beneficial actions for others.

Interactions of society: This idea is to create an interactive environment, similar to real society, in which participants could share their opinions with others about public issues. In particular, when the game is about to be lost, it provides an opportunity for players to identify problems and suggest methods for solving them.

Studies suggest that four aspects of board game designs can fit the application of a board game for SSI learning. The framework of this study, outlined in Table 1, helps participants (1) to form their opinions of an organization, (2) to enhance their knowledge and responsibility, and (3) to pay attention to other participants' topics.

Table 1. Study framework.

Design Ideas	Board Game Features	SSI Environment	The Design Idea for SSI Learning
1. Multirole simulation	Role-play simulations	Multiple opinions	• Establishing the opinion of roles • Learning to reach a consensus
2. Systemic situation	• Procedural rules • Feedback mechanisms	Science and system	• Constructing issue knowledge • Improving attitude for issue
3. Reflective goal	Goal orientation	Public problem solving	• Promoting personal metacognition • Caring about public issue • Paying attention to others
4. Interactions of society	Player interactions	Society and public	• Establishing the opinion of roles • Paying attention to others • Communicating the behaviors in issue

1.4. Research Aims

In this study, we developed an issue-situation-based board game named Water Ark based on four design ideas, i.e., multirole simulations, systemic situation, reflective goal, and interactions of society. These features help participants to construct opinions about game roles and enhance their competencies of water resource adaptation. Moreover, they pay attention to others and understand the topics of other roles in the game, which eliminate the gaps in learning outcomes. The research aims are outlined as follows:

1. To develop an educational board game that incorporates four design ideas involving multirole scenarios;
2. To evaluate the participants' opinions on organizations;
3. To evaluate the differences in participants' performance related to different organizations;
4. To explore the utility of design ideas for improving participants' attention on other roles' topics.

2. Materials

Water Ark is a board game for water resource adaptation (WRA) education. The aim of WRA education is to improve the public's WRA performance, including WRA knowledge, responsibility for the WR environment, and WRA behavior [6,40].

2.1. Water Ark Concepts

WRA is a multidisciplinary SSI. It relates to approaches to water resource (WR) sustainability under the influence of climate change. Those approaches focus on water management, including the provision and demand of WR, water footprints, and the effects of society on WR [41,42]. Table 2 outlines the learning objectives of Water Ark, which consist of water management knowledge (WMK), personal responsibility toward WR (PRWR), and personal action for public benefits (PAPB).

Learning Objectives	Contents
WMK	The participants should understand the WR management in WRA, such as WR maintenance, provision and demand of WR, water footprints, and the effects of society on WRs.
PRWR	The participants should have personal responsibility for the WR environment and willingness to act on WRA, such as caring about water sanitation and expressing opinions on water issue.
PAPB	The participants should realize the relationship between the WRA issue and the public, and have personal action of public and water benefits. For example, they take actions to raise objections about the action which harmed public.

2.2. Design and Rules of Water Ark

After the learning objectives and WRA-based concepts of Water Ark were provided, four design ideas were introduced, namely multirole simulations, reflective goal, systemic situation, and interactions of society, to improve participants' competencies and eliminate gaps in learning outcomes. Therefore, the aim of introducing design ideas in Water Ark was to construct roles, systems, and interactions related to WRA and to alter participants' opinions, knowledge, and metacognition about WRA. Water Ark has been developed and revised for more than four years. It was tested by cognitive psychologists, science education researchers, and environmental education specialists to ensure the quality of the game and its validity. Furthermore, we also evaluated the motivation of students who participated in the gaming activity. The measurement was a five-point Likert-type scale with 17 items, and results showed an average value of 4.32 (high motivation, from Likert-scale questionnaire, where 5 is the highest motivation).

1. The multirole simulation simulated the four main organizations involved in WRA based on the people in positions responsible for WR management. For example, the organization responsible for the provision of WR is the government and the organizations related to WR demand are in the industrial sector, the agricultural sector, and public guild. Each organization has individual production levels, activities, or actions that would enhance the organization in question or affect other organizations (Figure 1). For example, the government is in charge of formulating social and economic systems, the agricultural sector is responsible for food production, the industrial sector is responsible for electrical equipment production, and the public guild is responsible for providing clean and drinkable water for public consumption.

2. A systemic situation is used to construct the WRA system [41,43,44], including WR maintenance, WR provision, WR use and consumption, and the sociological and economic effects of WR. On the basis of the system and learning objectives, Water Ark has four simulated real-world scenarios, [24]:

Systemic influences: This scenario includes two parts. One part is called "climate influences", and participants need to draw a climate card and throw a dice. The result corresponds to the mean annual rainfall. The other part is called "system formulation", and the government should set water prices and taxes for this round.

Product trading: In this scenario, all organizations should do three activities. First, they take available WR from a common reservoir for resource acquisition. Second, organizations produce products based on human resources, WRs, production costs, and product prices. Third, organizations obtain products or earn money through product trading.

Technology development: The government and industrial sector improve technology to enhance water utilization.

National survival: The instructor examines public health. Public health is one of the indicators of organizations for scoring in the game. These indicators are determined by the organizations' provision of adequate food and clean drinking water.

Different organizations deal with different topics in various scenarios. Participants use various strategies to achieve the highest scores and to complete small goals in each situation. Table 3 presents the topics each organization faces in each game event. All organizations explore all aspects of WR management over seven events.

3. A reflective goal is the principal idea in Water Ark. Three layouts are employed to promote participants' reflection as follows:

Composite score indicators: These indicators are not only scored based on environmental indicators (e.g., water resources and public health) but also on an economic indicator (e.g., an organization's cash). Each organization competes with others to strive for the highest score. However, the game is terminated if public health drops below a certain level, thereby encouraging players to constantly monitor their situation.

Interlocking indicators: The indicators are influenced by others in the game. For example, if a player wishes to earn more money, they need water resources for producing, and then the available WR is reduced. Reduced WRs lead to a decline in public health, which in turn can lead to all the participants losing. Consequently, players must constantly evaluate and correct their in-game actions in relation to their effects on indicators.

Public indicators: Available WR and public health are related to other organizations. The available WR is shared by everyone, and all organizations must consider public health when using the available WR. To achieve high scores, participants must take public conditions into account.

Following this idea, in the game, the primary objective of an organization is getting the highest score. The score is made up of the organization's cash, the organization's water resources, and public health (Figure 2). Under the setting of reflective goal in Water Ark, participants receive low scores or lose the game if they only care about themselves and ignore public benefits, available WR, and other organizations. Therefore, they should consider how to maintain public health and should pay close attention to other organizations and related topics.

4. Interactions of society refers to the real operating mode of society. Participants are divided into groups, and teamwork in a group is required to win the game. The game is designed to be open to social and interactive environments in each game event (except climate influences and national survival), such as arguing for water prices and tax rates, asking for productions, and trying for specific benefits. Moreover, groups can compete, negotiate, cooperate, or hold discussions with each other autonomously.


(a)

(b)

Figure 1. *Cont.*

(c)   (d)
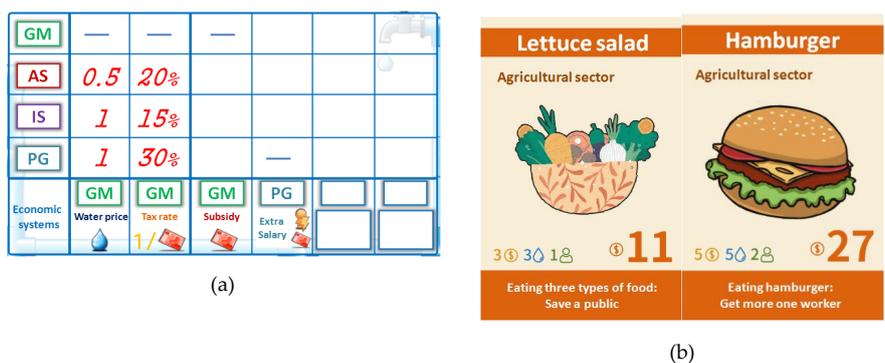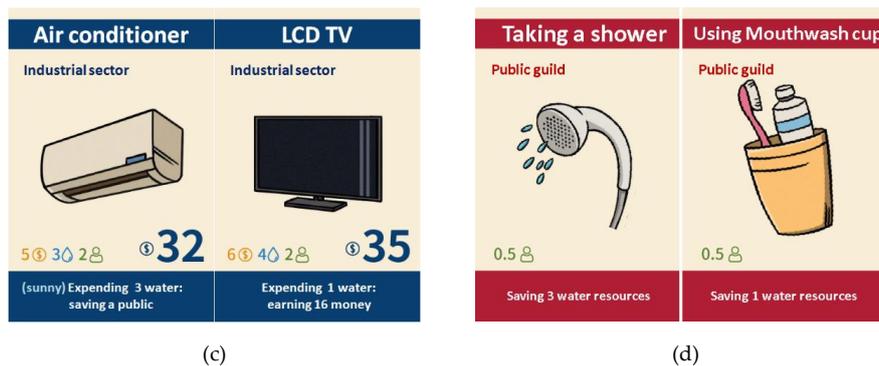
Figure 1. In Water Ark, participants can choose the organization that they wish to play as. The table in picture (**a**) is used to present the information on water prices and the tax rate made by GM. GM, government; AS, agricultural sector; IS, industrial sector; PG, public guild; The cards in picture (**b**) are food produced by AS; the cards in picture (**c**) are equipment produced by IS; and the cards in picture (**d**) are water-saving methods done by PG. The information at the bottom left is the cost of the card, the value at bottom right is the selling price, and the sentence at the bottom is the function of the card in the game.

Table 3. Water Ark's game scenarios, events, and corresponding learning objectives.

Game Scenarios	Game Events	Learning Objectives	The Topics of Each Organization			
			GM	AS	IS	PG
Systemic influences	Climate Influences System Formulation	• WR maintenance	v	v	v	v
		• The provision and demand of WR	v			
		• The effect of society and the economy on WR				
Product trading	Resource Acquisition	• The provision and demand of WR • Personal responsibility and willingness to act • Personal action of public benefits	v	v	v	v
	Production of Products	• The effect of society and the economy on WR • Water footprints • Personal responsibility and willingness to act		v	v	v
	Product Trading	• The effect of society and the economy on WR		v	v	v
Technology development	Technology Development	• The provision and demand of WR • Water footprints	v		v	
National survival	National Survival	• The effect of society and the economy on WR • Personal action of public benefits	v	v	v	v

Notes: GM, government; AS, agricultural sector; IS, industrial sector; and PG, public guild.
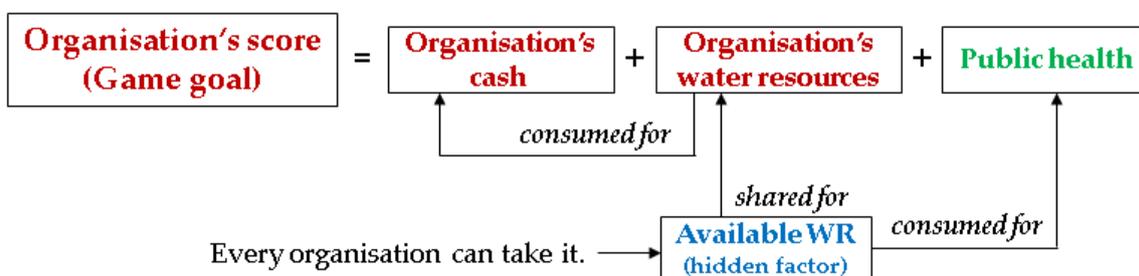
Figure 2. The relationship between score indicators, hidden factor, and the game goal. About the indicators, the red ones are individual factors, the green one is a public factor, and the blue one is a public factor supported for all organizations.

2.3. Playing Process of Water Ark

Water Ark was designed to guide participants in experiencing the various roles related to WRA. According to the design of the systemic situation and interaction of society, Water Ark frames a sequential process with four scenarios that provide an open and interactive decision environment. The participants can plan and execute their strategies, and they can also compete or cooperate with others. Therefore, they can use various strategies to achieve their objectives, which gives flexibility to players. The game process is illustrated in Figure 3.

At the beginning of the game, participants are grouped into four teams. Each team is required to choose a role to play one of the following roles, i.e., the government, industrial sector, agricultural sector, or public guild. Then, participants face seven events in each round until the game ends. The scenarios in sequence are systemic influences, product trading, technology development, and national survival, which include a total of seven events. In each round, participants can implement strategies and interact with other players to gain more benefits. The game ends after four rounds, and the playing time is approximately 120 minutes. The organization that obtains the highest score is the winner. This process is expected to refine the knowledge and WRA abilities of the participants, and it could help participants understand the systems involved in WRA. Learners also realize that SSIs relate to the public and other organizations, and therefore they should pay close attention to topics related to other roles.
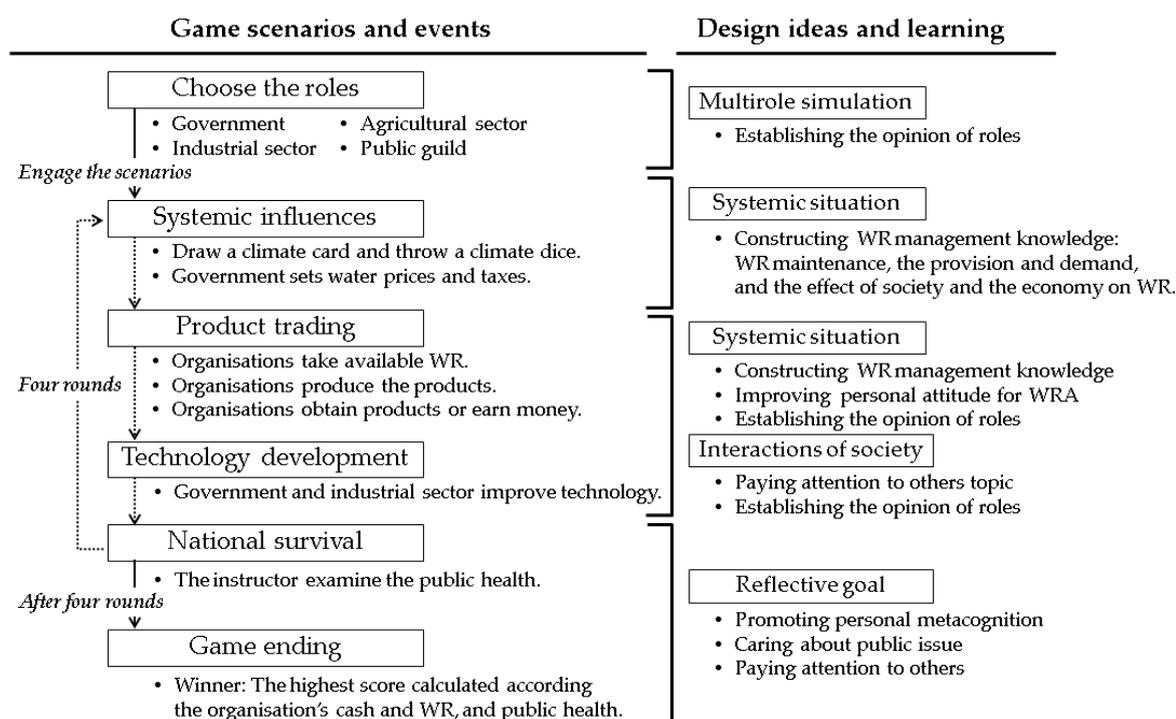

Figure 3. Playing process of Water Ark.

3. Methods

3.1. Measurements

In this study, we developed the following four measurements to evaluate participants' performance:

WMK test: This test was comprised of 11 multiple-choice questions, which were used to assess participants' understanding of WR management concepts. The questions referred to the content of the "Adaptation Strategy to Climate Change in Taiwan" [41]. The 11 items in the WMK test covered four components, i.e., WR maintenance, the provision and demand of WR, water footprints, and the effects of society on WR, such as "Which one requires the most water? (a) 200 g

of chicken; (b) 200 g of rice; (c) 200 g of vegetables; (d) 200 g of beef" and "Climate change may increase the risk of water shortage. Which of the following adaptation methods is most appropriate? (a) Build reservoirs to increase water storage capacity. (b) Develop hillside land and look for mountain spring water. (c) Comply with nature, and nature can adjust itself. (d) The nation saves water without wasting". In the test, participants were asked to choose answers. Students earn one point if they choose the right answer for each item.

PRWR questionnaire: This questionnaire was comprised of 17 questions developed to evaluate participants' responsibility for the WR environment (10 items) and willingness to take action on WRs (7 items) [45]. Examples of questions are "Do you care about water sanitation near your home?" and "Would you take the initiative to express your opinions on water and environmental issues and implement your ideas in everyday life?" This questionnaire was answered on a five-point Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree), and the participants were instructed to select an option that reflected their feelings from the five options. The internal consistency reliability score for this questionnaire was 0.85 (Cronbach α).

PAPB questionnaire: This questionnaire was used to determine whether participants had implemented the actions with public benefits in the board game, to evaluate the PAPB. It consisted of five items, including "In the game, I took action to raise objections when an organization exploited WRs without considering the needs of other organizations." If any action was taken, participants answered "Yes"; otherwise, they answered "No", for a total of five questions.

Self-evaluation questionnaire: The questionnaire consisted of open-ended questions, which were used to obtain participants' opinions of their own organization after playing Water Ark. In addition, participants were asked to provide their thoughts about design ideas for eliminating the learning gap in multirole scenarios. The code numbers of participants were #GM01–#GM05 for government, #AS06–#AS10 for the agricultural sector, #IS11–#IS15 for the industrial sector, and #PG16–#PG21 for the public guild.

3.2. Procedural and Statistical Analysis

This study was conducted at a college whose average percentile rank (PR) was about 53, in Taiwan (total number of schools is 160). There were 21 participating students, ranging in age from 18 to 20 years, 9 of whom were men, and 12 were women. Participants were recruited from a general course named "Issues in Environmental Science," which means their common knowledge and background of the WRA issue could be ordinary. Note that the small sample size is a significant limitation of this study in discussing and generalizing its results.

The participants were randomly divided into four groups of three to four participants per group. To evaluate the participants' learning outcomes, a pretest and posttest were employed in the research design. The research process is displayed in Table 4. This Water Ark study had two main activities. The first activity was learning and understanding the game process. The second activity was playing the formal role-playing game with multirole simulation. Each activity took 2 hours.

Table 4. Research process for Water Ark.

Time	Content	Tool
30 min	Pretest	♦ WMK test ♦ PRWR questionnaire
30 min	Game rules describing	Game rules describing
120 min	First activity of Water Ark	Board game: Water Ark ♦ PAPB questionnaire
120 min	Second activity of Water Ark	Board game: Water Ark ♦ PAPB questionnaire
30 min	Posttest	♦ WMK test ♦ PRWR questionnaire ♦ Self-evaluation questionnaire

The data collection and analysis methods employed were as follows: (1) A content analysis method was employed to evaluate participants' opinions about their own organization from a self-evaluation questionnaire after they played the game. (2) The WMK test and PRWR questionnaire were implemented before and after the game, and the PAPB questionnaire was used to evaluate the participants' performance during and after the game. Paired samples *t*-tests and power analysis were used to evaluate participants' learning performance. Because the small sample size in this study, data were also analyzed according to effect size. (3) To analyze the difference in participants' performance between each organization, the data were collected from the WMK test, the PRWR questionnaire, and the PAPB questionnaire, and an analysis of covariance (ANCOVA) was conducted.

4. Results

4.1. Appropriate Opinions of Participants in Organizations

According to the results of the self-evaluation questionnaire, the students in each organization formed appropriate opinions. The students who played the government role understood that governments play a crucial decision-making role in WRA by formulating social and economic systems. For example, WR should be allocated in a reasonable manner to optimize their utilization.

#GM01: *While playing in this game, I understand that the decision made by the government is very critical, it need to take care of everyone.*

#GM02: *The government must take into account the needs of all other groups. We should allocate resources effectively, otherwise it may cause famine.*

#GM03: *I think the government should make a reasonable system of water price according to specific real needs, and improve water utilisation and actual benefits*

Furthermore, they reported that the government could improve social operations by formulating policies.

#GM04: *I feel that the government has a great influence on policy.*

#GM04: *Our group has established a reward law: If someone saves water, they can get rewards. Additionally, this policy also encourages the industrial sector to produce the water-saving devices.*

#GM05: *Because the group of industry may spend a lot of water to make money, we should set higher water prices to prevent them from wasting water.*

Students in the agricultural sector group were aware of that sector's role as a food producer in WRA. Moreover, they also noted that this organization relies heavily on water.

#AS06: *Water consumption in agriculture is so much.*

#AS07: *Agriculture can produce food to determine public's survival.*

#AS08: *For the agriculture, the type of weather we faced is really important.*

#AS09: *In fact, the responsibility of agriculture is food supplying, but its products are really dependent on the weather.*

The students in the industrial sector reported that their sector's role is producing technological products to sell to, or help, other organizations.

#IS11: *I think the products produced by industrial sector are actually very important to people.*

#IS12: *In the game, we thought that the action of industrial sector was to making money by sell products.*

#IS13: *If we produced and sell products successfully, we can get a lot of money.*

The public guild students recognized the role of the public guild in human resource allocation and maximizing public benefits.

#PG16: *The main responsibility for us is to provide human resources to other groups in order to produce goods. It needs to be distributed the human resources properly.*

#PG17: *The group of public guild is responsible for providing human resources, and the amount of them will affect the production of each organization.*

#PG18: *The group of public guild has to think about how to maximize the public benefits.*

4.2. Positive Performance of Participants

In Table 5, the average value of the correct answer fill rate (CAFR in Table 5) in the posttest (75%) is higher than in pretest (66%). Moreover, according to the *t*-test results, the posttest values were significantly higher than the pretest values for both the provision and demand of WR ($t(20) = 3.20$, $p < 0.01$) and for the WR management test ($t(20) = 2.89$, $p < 0.01$). Scores for WR maintenance, the effect of society and economy on WR, and water footprints were not significantly different between the pretest and posttest ($t(20) = 2.89$, $p = 0.36$; $t(20) = 2.89$, $p = 0.43$; $t(20) = 2.89$, $p = 0.10$, respectively). It could not be precisely claimed that the statistical significance with low observed power was caused by the limitation of sample size, but the pretest and posttest coefficients of effect size were high (0.14–0.71). Students understood that saving water for public use was a suitable adaptation method and they appropriately understood the relationships between environmental protection and economic development.

According to the contents of the self-evaluation questionnaire, participants also indicated that after playing the game, they realized that WRA issues are both scientific and social, and that water resource plays a vital role in the development of organizations.

#AS08: *In addition to the development of economy, we cannot ignore the importance of water. We should think carefully about how to maintain a balance between the economy and water resources so that water resources can be used sustainable.*

#AS09: *Because the water footprint of food is large in Taiwan, the government should promote advanced water-saving technologies and support water-saving agriculture actively.*

Table 5. Results of the water management knowledge test.

Variables		Mean (SD)	CAFR	t	*p*-Value	Observed Power	Effect Size
WR maintenance	Posttest	2.52 (0.68)	85%	0.94	0.358	0.07	0.24
	Pretest	2.33 (0.91)	78%				
Provision and demand of WR	Posttest	2.24 (0.77)	75%	3.20	0.004	0.50	0.71
	Pretest	1.71 (0.72)	57%				
Effect of society and economy of WR	Posttest	1.38 (0.67)	69%	0.81	0.428	0.07	0.14
	Pretest	1.29 (0.64)	65%				
Water footprints	Posttest	2.14 (0.48)	71%	1.70	0.104	0.16	0.38
	Pretest	1.95 (0.50)	65%				
WR management test	Posttest	8.29 (1.55)	75%	2.89	0.009	0.42	0.65
	Pretest	7.29 (1.68)	66%				

Table 6 presents the participants' performance in the PRWR questionnaire. The values for the posttest results were significantly higher than the pretest results ($t(20) = 4.21$, $p < 0.01$ and $t(20) = 4.77$,

$p < 0.01$). Moreover, the effect size was large (1.53, 0.90). Examples of items that were highly rated in the questionnaire are "Deliberating on the conservation and reuse of water for environmental protection", "Encouraging family and friends to purchase water-saving equipment", and "Forming opinions proactively for the environment". Accordingly, participants generally reported that they were motivated to be responsible for the WR environment:

#PG18: *I will more cherish about the water resources and start to care about the water-related issues.*

#PG20: *I will tell my friends and family about the correct concept of using water resources I learned in the course, so that water resources can be sustainable.*

Table 6. Results for the PRWR questionnaire.

Variables		Mean (SD)	t	*p*-Value	Observed Power	Effect Size
Responsibility for the WR	Posttest	4.41 (0.39)	4.21	0.000	0.67	1.53
	Pretest	3.76 (0.46)				
Willingness to act WRA	Posttest	3.99 (0.52)	4.77	0.000	0.81	0.90
	Pretest	3.56 (0.42)				

Table 7 illustrates the actions of participants for public and WR benefits taken during the playing of Water Ark. The results after a second playing were notably improved over those after a first playing ($t(20) = 4.05$, $p < 0.01$), with a large effect size (1.10). Students could take action by supporting the production of water-saving devices for the public and preventing the inappropriate use of water. These findings are in accordance with the results from the self-evaluation questionnaire:

#IS11: *I think we can start from our behaviours and affect the people around us, to create the "Butterfly effect".*

#PG16: *I will carry out what I have learned into action in the future.*

#PG20: *In the real life, the concept of water is important. We have to reduce the water wasting and stop people to do the action in water wasting.*

Table 7. Results for the PAPB questionnaire.

Variables		Mean (SD)	t	*p*-Value	Observed Power	Effect Size
Actions taken in the game	Posttest	3.31 (1.04)	4.05	0.000	0.44	1.10
	Pretest	2.14 (1.08)				

4.3. Nonsignificant Differences of Participants' Performance Between Different Organizations

Table 8 illustrates the difference in participants' WMK between each organization. The result of the ANCOVA, summarized in Table 8, revealed that in the majority of categories, no significant difference was observed in the knowledge of participants from the different organizations. The only significant difference was that for the effect of society and economy of WR. The participants who played the role of government had greater knowledge than the agricultural sector group in ($F = 1.57$ and $p = 0.23$, see Table 8). These results indicate that students' organizations did not lead to critical differences in learning outcomes.

An ANCOVA performed on students' PRWR posttest results with pretest results as the covariate indicated that no significant differences existed between the other three organizations ($F = 1.71$ and $p = 0.20$, see Table 9). Notably, the students in the public guild group exhibited a higher willingness

to act in terms of WRA (F = 7.39 and $p < 0.001$) than the other groups. Moreover, the results of the in-game PAPB questionnaire indicated that the public guild group had performed significantly more actions than the industrial sector groups (F = 2.07 and $p = 0.14$, see Table 10).

Table 8. WMK test results for differences between organizations.

Variables	SS	df	MS	F	p	Post hoc
WR maintenance						
Organizations	0.39	4	0.09	0.19	0.93	
error	7.72	15	0.52			
Total	143.00	21				
Provision and demand of WR						
Organizations	1.21	4	0.30	0.59	0.68	
error	7.74	15	0.52			
Total	117.00	21				
Effect of society and economy of WR						
Organizations	1.48	4	0.37	1.57	0.23	GM > AS
error	3.53	15	0.24			
Total	49.00	21				
Water footprints						
Organizations	0.24	4	0.06	0.26	0.89	
error	3.40	15	0.23			
Total	101.00	21				
WMK test						
Organizations	10.34	4	2.59	1.57	0.23	
error	24.72	15	1.65			
Total	1490.00	21				

Notes: GM, government and AS, agricultural sector.

Table 9. PRWR questionnaire results for different organizations.

Variables	SS	df	MS	F	p	Post hoc
Responsibility for the WR environment						
Organizations	0.43	3	0.14	1.74	0.20	PG > IS
error	1.23	15	0.08			
Total	340.78	20				
Willingness to act WRA						
Organizations	1.79	3	0.59	7.39	0.00	AS > IS; PG > GM;
error	1.21	15	0.08			PG > AS;
Total	327.39	20				PG > IS

Notes: GM, government; AS, agricultural sector; IS, industrial sector; and PG, public guild.

Table 10. PAPB questionnaire results for different organizations.

Variables	SS	df	MS	F	p	Post hoc
Action for public						
Organizations	5.14	3	1.71	2.07	0.14	PG > IS
error	13.22	16	0.83			
Total	256.00	21				

Notes: IS, industrial sector and PG, public guild.

5. Discussion

5.1. Issue Situations for Opinions on Forming Roles

The results from the self-evaluation questionnaire demonstrated that participants in each organization related to WRA believed that the topics addressed in the game were similar to real-world issues. Students reported that the government group focused on supplying and allocating resources, as well as devising optimal adaptation methods using economic systems and policies. WRA is one of the principal response strategies to climate change for ensuring water sustainability. Therefore, it is critical for governments to consider this topic when planning development policies for WR sustainability [41,43], such as improving the efficiency of water use, establishing the mechanism of water allocation, and providing water supply sources. The agricultural sector, which consumes a large quantity of water in producing food products, is a key organization because WRs are affected by climate change. The water footprint of food products must be considered and production plans must be formulated for WRA [46]. Our results indicate that students in this study formed notable opinions about these topics. Participants in industrial sectors also reported that the topics were similar to real-world issues, such as choosing between producing goods to earn money, saving water, or developing technology for WRA [47]. Moreover, the students who played the public guild noted that their main responsibility was to maximize public benefits [13].

The game helped students form opinions through role playing and experiencing systemic situation. These activities allowed participants to apply their ideas within a specific framework, which could expand their ideas and competencies [48]. Furthermore, it provided an opportunity to train students to contemplate professional situations [2]. Moreover, this activity could strengthen participants' understanding of the relationships between various positions related to SSIs [23]. Students in previous studies also reported these effects. For example, #PG17 and #IS11 reported on role playing and systemic situation and #AS08 and #PG16 reported on the interactions of society:

> #PG17: *While I began to engage in the situation, I had understood more about the topic of the role I played.*

> #IS11: *We noticed that this game situation was like real world. We should be careful to produce products which people will be willing to buy, to increase our income.*

> #AS08: *The price of water is very influential to us. Our organization is an important role for the production of food but need a lot of water, so we decided to talk with government about the price of water.*

> #PG16: *After discussing with the members of our group, we think about that if we want public to survive, we need to ask other groups to do the strategies about water saving together.*

More than one organization in society is involved in WR issues, and their reasons for using WRs are different. Although the interactions between them in real society is too complicated to learn, students must understand the positions of different water-related roles and comprehend related issues [49].

5.2. Game Features for Improving Participants' Performance

WMK posttest values were significantly higher than those for the pretest results. The correct answer fill rates in the posttest at four parts are 69% to 85%, which are similar to other teaching activities for climate change adaptation education (65% to 83%) [50–52]. This means that after playing Water Ark, students learn the knowledge about water management. Students' self-evaluation suggested that the situational feedback mechanism was the main factor in helping students learn about WRA:

> #GM04: *The development of technology and facilities can help us save public and water in the game. Because of it, we understand the relationships between some action and water resource adaptation.*

#PG21: *If we earn the money more, we can buy more water-saving equipment. If we consume water less, the others can develop well. There are relationships between economy and water resource.*

These responses can be explained by game-based learning. The corresponding feedback mechanism reflects the results produced by the participants after inputting actions, which could help participants adjust their cognition based on the feedback to obtain a more accurate conception [28,30,32]. This mechanism can also be useful for issue-based learning. For example, it could be useful in systemic SSI-based situations (such as scenarios related to the climate, impact uncertainty, identification adaptation solutions, and implementation adaptation [44,53].

The increase in personal responsibility for WRA could be linked to experimental learning from certain features of the game, including role-playing, simulated situations, and procedural rules. Experimental learning provides a simulated environment to engage learners in facing issues or problems. Because they are in a realistic situation, learners exhibit personal emotion and motivation in solving said problems [54]. Moreover, if learners solve problems successfully, it can enhance their self-efficacy, which can strengthen their willingness to act [55], subsequently increasing their sense of responsibility. Participants' responses were in accordance with this hypothesis:

#IS12: *Water Ark created a situation which engaged me to recognise the role's position I played. Additionally, it made me reflect about the topic of this role and his decisions what I made in game.*

#PG17: *When we keep the public health successfully, we started notice it is important to save water. We also realised that we should have the responsibility to do the action for saving water*

According to the responses of self-evaluation, it appeared that participants of the gaming experience motivated them to become more responsible. As a result, after playing Water Ark, they attempted to undertake actions for the public good and apply what they had learned in the game to their daily life.

#GM04: *Through playing the role in this game, I realized that everyone will be affected by WRs. We should actively solve WR problems in real life.*

#IS14: *Through the discussing and communicating about water resource issues in this game, I started to care about the sustainability of water resources and reflect on my activities.*

#PG16: *Through playing this game, it made me reflect on caring about the environment we lived, and I will lead my friends in the implementation of the preservation of the environment.*

#PG17: *I could recognize the positions of different roles through the game experience and decision making, and paid attention to the perspective of other roles.*

#PG19: *Through the role-playing experience of this activity, I had learned the correct actions what we should do in the water resource issue. I will implement is in the future.*

5.3. Four Design Ideas for Promoting Participants' Attention for Other Roles' Topics

In the WMK test, there are 69% to 85% correct answer fill rates in the posttest, and no significant difference was noted between the groups. This suggests that the participants may have properly understood factors related to the WRA issue, including those for organizations related to WMK. The participants' responses in the self-evaluation also indicated that they began to consider other organizations' topics of concern.

#GM02: *After realising the importance of public health, we began to pay attention to each organization and focus on the overall topics, such as consuming their own resources to help industrial sector to save the public, and buying water-saving equipment for agriculture organization.*

#GM03: *In a round, when we increased the taxation of industrial sector, the industrial organization protested to us that they always donated their remaining water to other organizations and had no water to produce goods to earn the money. The objections by them against us prompted me to reflect that we should be able to know what they had done.*

#AS08: *In the first round, we ignored that the needs of public health are supported from all of organizations. Because we only make our own profit, the public health declined rapidly. These circumstances caused all organizations to begin to comprehend the other organizations' topics and discuss with others.*

#AS09: *Because the water footprint of food is large in Taiwan, the government should promote advanced water-saving technologies and support water-saving agriculture actively. Hence, we proposed opinions on the government's taxation.*

#IS11: *I think the products produced by industrial sector are actually very important to people. Therefore, we ask public guild what kind of equipment they needed before we producing.*

#PG18: *We noticed that the agricultural sector needs a lot of water to produce food for public, but they lacked funds to purchase water-saving equipment. Therefore, we spent our money to buy the equipment for them.*

#PG19: *Our group took a lot of water resource, so the other groups' water is too less to do some methods for public. Finally, we were aware to the operation after we losing the score of public health.*

On the basis of the responses, we inferred that participants' comprehensive knowledge of WMK resulted from the application of two design aspects, reflective goal and the interactions of society. Students usually failed the first round of the game. Reflective goal encouraged them to attempt to understand the idea common knowledge, including that for topics of concern for the different organizations related to WMK (data from #GM02, #AS08, #IS11, and #PG19). The interactions of society provided the opportunity for participants to reach a consensus about WMK actions. As a result, participants had similar opinions and acquired a comprehensive understanding of the concerns of other organizations (data from #GM03, #AS09, and #PG18). However, participants' understanding of the effect of society and economy on WRs was significantly different between those playing the government and agricultural sector. Participants' responses indicated that this disparity could have been caused by participants in the government group believing that the government played a principal role in formulating a societal and economical system, whereas the participants in the agricultural sector focused primarily on producing food.

The ANCOVA of the PRWR questionnaire revealed two principal outcomes. First, responsibility for the WR environment was not significantly different between organizations. Second, participants in the public guild were more willing to act with regard to WRA than the other groups. Responsibility was influenced by the integrated effects of two design ideas, reflective goal and the interactions of society. Participants' responses revealed that reflective goal promoted their metacognition of their responsibility regarding WRs, and they implemented their responsible behaviors through the interactions of society.

#AS10: *All of us realised own responsibility on public health. For example, our group need to produce enough food for public; the Government should give us the preferential price of water; the industrial sector also provided us water-saving devices; the public guild made the priority for us to get worker.*

#IS14: *The wrong decision led the public health to decline rapidly, which made us realise that water resources are limited. Additionally, we should give public good quality of life and show solicitude for other organizations.*

#PG16: *The main responsibility for us is to provide human resources to other groups in order to produce goods. It needs to be distributed the human resources properly.*

#PG20: *The responsibility of our group is taking care of public. However, the workers we dispatched to Agricultural sector is too little to produce food. It caused all of us decreasing the score of public health. This experience let me notice the importance of communicating with other organizations.*

The integrated effect of the two design ideas, promoted the responsibility regarding WRs of all participants equally, but the participants in the public guild had a higher willingness to act towards WRA. Because the public guild role is closer to the real role of students, they could have had a greater sense of identity, which could have led to them having an increased awareness of the learning theme and more motivation to take action [56]. Moreover, Water Ark was designed as a competitive game environment, with only one group able to win. The situations and topics of the public guild are concerned with taking care of the public. To win the game, it is assumed that the public guild would have to enhance their willingness to take action related to WRA for the public good. This phenomenon was also observed in the self-evaluation responses. It could be explained by the theory of planning behavior, which predicts the links between attitude, behavioral intention, and behavior [57]. Thus, the relatively high willingness to act is attributed to positive attitudes towards winning the game. Moreover, the theory of planned behavior could explain the ANCOVA results for action for the public good, which revealed that the public guild achieved better results than those in the industrial sector. The majority of industrial sector participants reported paying attention to making money and ignoring the care of the public.

The results revealed that the four design ideas helped the participants to focus on integral topics at issue, which could eliminate the learning gap. However, the public guild students were more willing to act than others, which was caused by the competitive environment and conditions to win. Certain conditions and situations should be revised or added, for example, a cooperative task for the public could be designed or interactive topics could be included to promote discussions between groups.

6. Conclusions and Implications

The characteristics of SSIs, such as systemic scientific contents, public in society, multiple opinions about topics, and openness, were integrated in the solutions. Therefore, for SSI-based learning, this issue-based board game can be a learning tool for students. Role playing in simulated situations and feedback mechanisms could help students actively participate in related practices and change their disposition. To eliminate the potential learning gap in multirole simulations and expand the utility of issue-based board games, four design ideas were integrated into the Water Ark game environment. The designs allowed students to learn through participating in the game. Our findings did not reveal a difference in students' learning outcomes.

We demonstrated the diverse uses for the issue-situation-based board game which integrated four key ideas. First, the design of multirole simulations in a game helped students form multiple opinions on SSIs and the four organizations related to WR management. The integrated ideas also encouraged participants to understand other organization's topics. Second, the design of systemic situation helped in the construction of the system and the relationships between the factors involved in WRs, which improved the participant's perspectives and knowledge about WRA issues. Third, the design of reflective goal meant that participants lost the game if they ignored key factors. After they lost the game, they began reflecting on it through metacognition, which led them to discover the hidden key factors and consider common thoughts and knowledge. Fourth, the design of the societal interactions provided an interactive environment based on real-world societies, which inspired participants to propose their opinions and hold discussions with others to identify solutions. Additionally, the learners had a consistent thought process and responsibility towards WRA issues, which was a result of this study design.

Although implementing these four ideas expands the utility of board games with multirole simulations for promoting SSI-based learning, certain aspects of the design of Water Ark should be revised. Water Ark is a competitive game, and because the main concerns of one of the organizations (the public guild) was taking care of public health and its scores on public health were higher than

those of other organizations, the participants in the public guild had a greater improvement in their willingness to act regarding WRA than those in other organizations. Hence, the situations or conditions need to be revised, such as by designing cooperative tasks for public well-being and adding topics for interaction between groups.

This study based on Water Ark integrated four design ideas and created a flexible discussion space that is in line with the openness and multiple opinions required to overcome SSIs education. After playing the game, participants could continually and simultaneously adjust their opinions, knowledge, and disposition. Our findings suggest that implementing the four design ideas could help in the design of board games for SSI-based learning. In the future, we would analyze more data and implement additional experimental designs to obtain more definite results, such as creating a control group with a different policy or without any intervention, increasing the number of participants, and researching the relationships between the interactive processes, as well as learning performance during the game.

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