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Exploring Elementary School Students' Perceptions Towards Socioscientific Issues Through the Role-Playing GamePerceptions

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Abstract

This study develops the simulation game <Future City> with role-playing mechanism and inquiry-based learning structure aiming to enhance the elementary school students' perceptions towards socioscientific issues. The research was conducted through a learning activity in a public elementary school in Taiwan, collecting data through pre- and post-tests administered to sixth-grade students. During the game, students took on different social roles, engaged in interactions, and made decisions to explore issues such as environmental protection, economic development, and social justice. The main findings of this study indicate that after participating in the <Future City>game-based learning, students showed significant positive changes in their perceptions towards environmental and social issues. There were divergent opinions among students when balancing economic benefits with sustainability and development, reflecting their depth of thought in understanding the balance between economic development and environmental protection. The results of the research emphasize the potential of educational games in promoting students' understanding of socioscientific issues and the development of critical thinking skills.

Keywords: Socioscientific Issue (SSI), Issue Situation, Simulation Game, Roly-Play

1 Introduction

In contemporary society, as global challenges such as climate change, economic inequality, and social justice become increasingly prominent, the role of education becomes more important to teach students forsights. Particularly at the foundational education stage, effectively integrating these complex issues into teaching and inspiring students' critical thinking and problem-solving abilities are key to current educational reforms. Taiwan, as a society facing rapid social change and environmental pressures, needs to cultivate the next generation with a strong sense of civic awareness and responsibility. Against this backdrop, this study utilizes educational strategies such as role-playing mechanism and inquiry-based learning structure to explore how these methods help elementary school students gain a deeper understanding of and engage in socioscientific issues.

The significance of this research lies in role-playing mechanism and inquiry-based learning structure–the development of a simulated game which not only enhances students' understanding

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of subject matter but, more importantly, promotes their social participation and ethical reasoning abilities. By simulating real-world roles and scenarios, students can experience and analyze social issues from multiple perspectives. This teaching strategy helps students bridge the gap between theory and practice, enhancing their sensitivity to socioscientific issues and their abilities to reflect critically upon them.

The main purpose of this study is to evaluate the effects of role-playing mechanism and inquiry-based learning structurethe simulated game <Future City> on enhancing elementary school students' perceptions and engagement in socioscientific issues. The specific research questions include:

What are elementary school students' perceptions towards socioscientific issues?

How do elementary school students' perceptions change towards socioscientific issues after participating in the <Future City> role-playing game?

2 Related Works

2.1 Socioscientific Issues

Socioscientific Issues (SSI) encompass topics where scientific content intertwines with social, ethical, and moral aspects. For example, amidst the pandemic, scientific issues like droplet transmission, mask effectiveness, and virus mutations are vital concerns. However, response measures such as quarantine policies, social distancing, mask mandates, and vaccine distribution involve considerations from social, political, and economic sectors. Thus, while the pandemic originates from science, its response measures and impacts are inherently socioscientific. The importance of socioscientific issues in education is recognized. Sadler & Dawson [1] coined "Socioscientific Issues" (SSI) to explore historical and social-related contexts alongside scientific content.

In today's society, issues like climate change, economic inequality, human rights, and digital privacy increasingly impact civic literacy. However, Lewis & Leach [2] note that science often cannot resolve social, ethical, or moral issues arising from its applications. Yet, rational discussions are impossible without a thorough understanding of relevant science to identify key scientific issues. Past research indicates that teaching within socioscientific contexts enhances students' moral sensitivity, aiding overall moral development Fowler, Zeidler & Sadler [3]. Moreover, integrating information literacy instruction in education curriculum enhances students' abilities to identify and process information. Empirical studies suggest that engaging in formal and informal SSI environments resonates with students as they develop personal moral senses considering various perspectives Tsai & Jack [4]. Regarding integrating these concepts into educational practice, Sakamoto et al. [5] provide empirical evidence, showing that interdisciplinary curriculum design significantly enhances students' abilities to promote socioscientific decision-making. Zeidler et al. [6] argue that the importance of SSI research and practice in contemporary and future science education lies in students' need to engage with their world, driven by genuine understanding and purpose, rather than external coercion. These findings clarify the present study and facilitate students' understanding of the close relevance of SSI.

2.2 Role-playing Simulation Games

Role-playing is a commonly used educational method where students can better understand and experience different perspectives and perceptions by taking on different roles. This method is believed to increase learner engagement, promote deep learning, and enhance problem-solving abilities. Simulations have many functions for addressing the complexity of real-world situations Davidsson & Verhagen [7] and role-playing as a form of simulation allows learners to immerse themselves in simulated real-life scenarios, thereby enhancing their sense of presence and involvement.

Simulation games are a form of gaming designed to simulate real-world situations or systems, allowing players to experience and learn by playing roles. Hammer et al. [8] point out that the framework of games can help learners see outcomes faster and provide meaningful contexts for projects. Role-playing mechanism plays a crucial role in simulation games, where players typically assume specific roles and take corresponding actions in the game. According to Chernikova [9], role-playing in simulation games helps improve players' situational awareness and problem-solving abilities. By playing different roles, players can think about issues from different perspectives and learn to deal with challenges in various situations. Simulation games can also serve as a learning environment where students can try out different roles and experience different occupational scenarios, helping them better understand the relationship between theoretical knowledge and practical application. Additionally, Huang et al. [10] found that through participation in simulation games, students can develop critical thinking and decision-making skills in simulated scenarios. Role-playing games can also be used to cultivate collaboration and communication skills Prager [11]. Furthermore, according to Shih et al. [12], games involve players, thus inherently inducing learning motivation and enhancing active participation, meeting the basic requirements of a learning environment. They can provide an attractive learning environment where role-playing in simulation games also promotes cooperation and communication among players. Playing different roles requires cooperation to complete tasks or achieve goals, which helps foster teamwork and communication skills. By playing specific roles, participants can engage more deeply in discussions and analysis, generating greater interest and involvement in the issues or problems.

3 Game Design

The simulation game, named <Future City>is an extension of the City Auncel System designed by Lu et al. [13]. <Future City>focuses on socioscientific issues in Taiwan, particularly the survival crisis of the Formosan Leopard Cat. The simulation game is designed based on role-playing mechanism and inquiry-based learning structure, where students are assigned to one of five roles: government, conservation group, developer, farmer, and hunter. The design incorporates three modes of inquiry-based learning: structured, guided, and open-ended, that are implemented in the three rounds of the game. The structured and guided rounds aim to familiarize students with the operation of the system and establish a basic understanding of the game's issue background. The guided inquiry round guides students to conduct directed research, providing them with strong evidence and data to negotiate with others in the game. The open-ended inquiry round encourages students to express their perspectives and formulate strategies to verify their roles' positions.

In the simulation game, students investigate real data related to the survival of the Formosan Leopard Cat, covering four main categories of the data: water resources, land use, animal

conservation, and population structure. This data exploration helps them understand the underlying causes of the Formosan Leopard Cat's survival crisis, providing a basis for their participation in discussions and cooperation on urban development. Subsequently, students must balance role objectives and shape the future development of the city in their decision-making with the overall simulation game flow depicted in Figure 1.

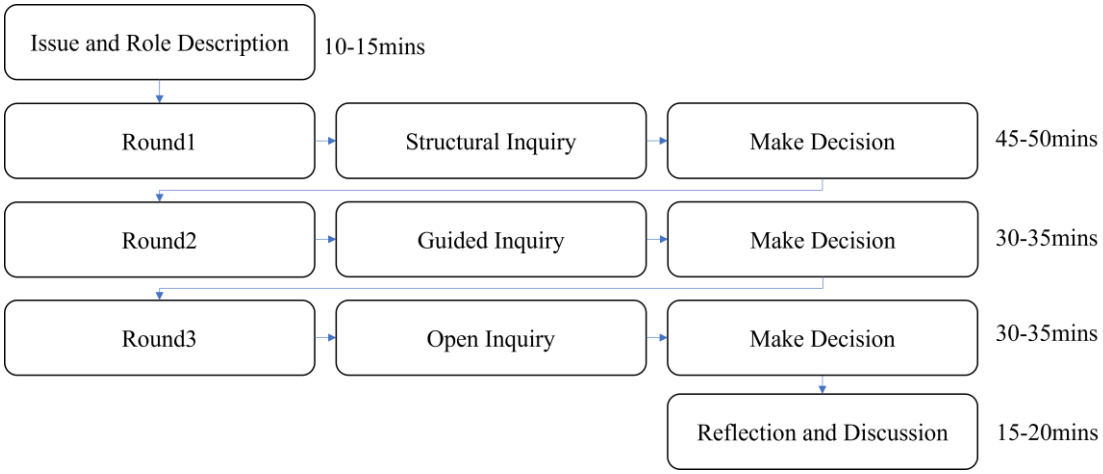


Figure 1: <Future City> Game Process

The simulation game consists of five modules: "Roles," " Mission Objectives," " Inquiry Data," "Decision Simulation," and "Visualization of Values".

3.1 Role Design

In the game, role design aims to simulate how different stakeholders interact in the real world and influence environmental and social issues. Each role has its own background, responsibilities, goals, and challenges. Students must assess and balance the concepts of national development and sustainability through the interests of different roles. The five roles in the activity are: government, conservation groups, developers, farmers, and hunters, each with specific tasks and objectives reflecting the positions and actions of different interest groups in the real world when facing the Formosan Leopard Cat crisis. Through the design of role tasks, participants are encouraged to gain a deeper understanding of the various factors contributing to the Formosan Leopard Cat's survival crisis.

Government: Responsible for finding a delicate balance between economic development and environmental protection. This role requires formulating and implementing a series of policies that promote both economic growth and the protection of natural environments and wildlife, such as the survival of the Formosan Leopard Cat. The success of government officials depends on their ability to balance public interests, environmental sustainability, and economic benefits, making wise decisions amidst conflicting interests.

Conservation Group: Represent the voice of environmental protection. Participants in this role dedicate themselves to protecting the endangered Formosan Leopard Cat in the Miaoli region and raising awareness of the importance of ecological conservation. Conservation group members not only actively promote conservation measures but also collaborate with the government and other stakeholders to seek effective methods of protecting the Formosan Leopard Cat's habitat. Their work involves research, education, advocacy, and on-the-ground

conservation activities, aiming to create a more harmonious coexistence environment.

Developer: Students playing this role face the challenge of balancing economic interests and respecting environmental protection. As the main force driving regional development and construction, developers must consider ecological conservation requirements in their development plans while ensuring the economic feasibility of their projects. This requires developers to actively explore innovative construction methods and sustainable development strategies in the planning and execution processes.

Farmer: The farmer role embodies the tension between agricultural activities and wildlife conservation. Participants will play the role of agricultural workers, focusing on increasing agricultural productivity and quality while reducing negative impacts on the environment. Farmers need to adopt innovative agricultural practices to protect water sources and soil, coexist harmoniously with wildlife, and achieve sustainable agricultural development.

Hunter: Participants in this role face moral and practical considerations regarding the use of natural resources and wildlife conservation. Hunters need to find a balance between traditional hunting activities and contemporary conservation needs. Their behavior directly affects maintaining ecological balance and protecting endangered species such as the Formosan Leopard Cat.

Through the design of these roles, participants gain a deeper understanding of and engage in solving environmental issues such as Formosan Leopard Cat conservation through interaction, collaboration, and conflicting interests, thereby increasing awareness of and action for ecological conservation.

3.2 Mission Objectives

Mission objectives consist of character values, personal missions, and common goals. The game's character values include national development index, environmental conservation index, money, agricultural output, hunting output, public opinion. Different characters need to balance certain specific values, which belong to the unique decision-making factors of that character in the game. The design of character missions is to drive students to further immerse themselves in the setting of the character when playing roles, reducing the problem of students breaking away from the character's setting due to personal emotions and actual social relationships. In order to deepen the conflicts of interest and positions between characters, further design common goals to encourage students to generate thoughts on balancing sustainability and development during the game. Table 1 shows the unique values assigned to each character.

Table 1: Mission Objectives Table of <Future City>

Role	Unique Values	Mission Objectives	Common Objectives
Government	1. National Development Index 2. Government Satisfaction 3. Money	1. Government Satisfaction > 60% 2. At least 1 public project	Environmental Conservation Index > 60%, National Development Index > 60%
Conservation Group	1. Environmental Conservation Index 2. Public Opinion	1. Environmental Conservation Index > 70%	

		2. At least 1 environmental project
Developer	1. National Development Index 2. Public Opinion 3. Money	1. Money > 600 2. At least 1 building project
Farmer	1. Agricultural Output 2. Money 3. Public Opinion	1. Agricultural Output > 300 2. Money>200
Hunter	1. Hunting Yield 2. Money 3. Public Opinion	1. Hunting Yield > 300 2. Money>200

3.3 Inquiry Data

In this game, exploratory data consists of a multidimensional, interdisciplinary collection of data and information aimed at delving into various factors affecting the survival of the Formosan leopard cat, including natural environment, human activities, and socio-economic structures. It provides data relevant to the survival of the Formosan Leopard Cat in the Miaoli region of Taiwan. Background information includes water resources, land use, animal conservation, and population structure, presented through a system webpage with diverse information, including text, charts, and interactive maps.

Water Resources: This includes basin data, water quality indicators, and pollution source analysis, providing a comprehensive understanding of the water environment in the Miaoli region. These data come from government open databases and environmental monitoring stations, detailing indicators such as river pollution levels, pH values, heavy metal content, and biochemical oxygen demand. Through the analysis of this data, participants can explore the potential impacts of water quality changes on the Formosan Leopard Cat and its ecosystem.

Land Use: This includes land use patterns, terrain, and land cover, provided by remote sensing imagery and Geographic Information Systems (GIS) analysis, showing changes in land use in the Miaoli region over the past few decades. Participants can understand how land development, agricultural expansion, and urbanization processes affect local ecological environments and wildlife habitats.

Animal Conservation: This focuses on the biological characteristics, habitat range, migration routes, and anthropogenic threats to the Formosan Leopard Cat. It provides information such as Leopard Cat observation records, the effectiveness of protected areas, and statistics on roadkill accidents. This data helps participants understand the urgency of Leopard Cat conservation and explore how ecological conservation measures and human activities adjustments can improve the Leopard Cat's living environment.

Population Structure: This reveals the population distribution, age structure, and population dynamics over time in the Miaoli region. These data, through statistical analysis, can reflect the indirect effects of regional development, urban-rural migration, and economic activities on leopard cat habitats. Students can use this data to explore the relationship between population changes and environmental pressures.

Through in-depth research and analysis of these rich exploratory data, participants can not only gain a comprehensive understanding of the challenges facing the Formosan Leopard Cat's survival but also use exploratory data as leverage for discussion, cooperation, and negotiation

with other roles. They can learn how to integrate interdisciplinary knowledge to solve complex socio-ecological problems, thus proposing innovative and feasible conservation strategies.

3.4 Decision Simulation

After going through the exploratory process, each character can sequentially choose an area for development, and the actions that can be taken by the characters are divided into five categories with a total of twenty actions as shown in Table 2.

Table 2: Twenty Action Simulation in 5 Categories

Category	Items
Architectural	Residential areas, Shopping centers, Amusement parks, Golf courses
Public Service	Industrial zones, Road development, River channel improvement, Parks
Conservational	Rural road construction, Protected areas, No hunting zones, Leopard cat habitats
Hunting	Hunting traps, Snares, Shooting poaching, Poisoning
Agricultural	Terraced fields, Orchards, Herbicides, Pesticides

These actions are designed based on the character's missions and actions related to the Formosan Leopard Cat's crisis, including construction, public, conservation, hunting, and agriculture. There are no specific actions that a particular character must perform, and there are no restrictions on characters repeating the same actions. However, each character can only take one action per turn. Based on the results of discussions between characters after exploration, cities are constructed, and the game system simultaneously simulates changes in all game values of the city.

To comply with real scenarios, even the same action in different areas would have different impacts. For example, building an industrial zone in the upper reaches of a river compared to building one in the lower reaches would have different impacts on environmental values. Similarly, the construction of a hunting ban area, whether chosen by conservation groups or developers, would also result in different numerical changes in environmental values.

3.5 Visualizing Data

By transforming the actions taken by students into visual results (Figure 2), various key information are effectively presented. This includes changes in common environmental values, changes in character values, mission completion status, and visual representation of the national landscape. Presenting changes in common environmental values allows students to observe how their decisions affect the entire ecological system. This may involve resource consumption, environmental changes, and other related factors. Through visualization, students can more intuitively understand how their actions affect environmental changes. Changes in character values are represented by graphical progress bars. By visualizing these values, students can clearly see the changes in their characters' decision-making process, helping them assess the effectiveness of their strategies. Presenting mission completion provides students with a clear indicator to assess whether their goals have been achieved, allowing them to clearly understand their progress.

The visual representation of the city's landscape as shown in Figure 3 allows students to better understand the overall status of the entire city. Students can better understand the overall situation of the country or society they are in, thereby adjusting their strategies more effectively.

Figure 3: Game Metrics

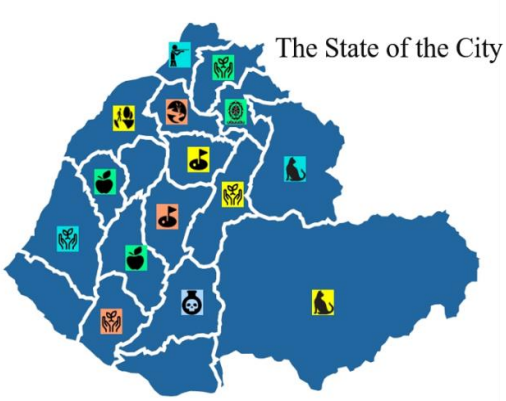


Figure 2: Cityscape Simulation

4 Research Method

4.1 Research Design

This study adopts a pre-learning activityal research design to investigate the impact of the role-playing mechanism and inquiry-based learning structure simulation game <Future City> on elementary school students' perceptions toward socioscientific issues. Through a pretest-posttest analysis, changes in students' perceptions toward socioscientific issues before and after participating in the activity are observed.

Before the learning activity, all students are given a pre-test questionnaire to collect their perceptions toward current socioscientific issues in Taiwan before playing the game. Subsequently, students play the role-playing mechanism and inquiry-based learning structure simulation game <Future City>. After the learning activity concludes, students are given a post-test questionnaire with the same content as the pre-test questionnaire to assess any changes in their perceptions toward the socioscientific issues.

4.2 Participants

This study was conducted in a public elementary school in Taiwan with sixth-grade students. The simulation game lasted approximately two hours. The class composition was based on regular class division, with a total of 23 students participating in the study, including 11 males and 12 females. Due to the game mechanics, the 23 students were randomly divided into one group of 5 and three groups of 6, making a total of four groups. The process of the research is outlined in Figure 4. The game was facilitated by the researchers in collaboration with the classroom teacher to conduct classroom management.

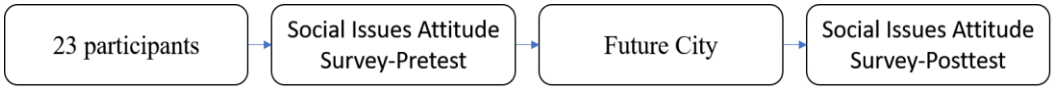


Figure 4: Research Process

4.3 Research Tool

The content of the Socioscientific Perception Questionnaire involves several important sustainability and development issues that Taiwan has faced in the past and present. The intention is to stimulate students' deep reflection and inspiration on sustainability issues. The design concept primarily aims to present different perspectives and viewpoints, enabling students to understand the multifaceted nature of socioscientific issues and encouraging them to make their own choices and judgments based on critical thinking. Additionally, the questionnaire aims to promote students' concern for sustainability and environmental protection issues and to encourage them to consider how to strike a balance between development and environmental protection in modern society.

The questionnaire structure is mainly divided into three parts: "Issue Explanation," "Position Explanation," and "Interactive Choices." In the "Issue Explanation" section, five different issues are included, each clearly defined, and providing students with both supporting and opposing viewpoints for each issue. In the "Position Explanation" section, to make the questionnaire results more instructive, detailed reasons for supporting or opposing each issue are listed. This not only presents facts but also considers the local environmental, economic, and social impacts, aiming to help students understand and consider their own positions to make more fully informed choices. In the "Interactive Choices" section, students are required to choose "support" or "oppose" for each issue and provide reasons for their choice, encouraging students to think and express their personal opinions. Table 3 illustrates students' considerations when choosing support or opposition lean towards sustainability or development in the respective issue.

Table 3: Expression of support and opposition for each issue

	Support	Opposition
Issue 1: Coral Reefs	Sustainability-oriented	Development-oriented
Issue 2: Plastic Waste	Sustainability-oriented	Development-oriented
Issue 3: Coal Power	Development-oriented	Sustainability-oriented
Issue 4: Anti-air Pollution	Sustainability-oriented	Development-oriented
Issue 5: Refinery	Sustainability-oriented	Development-oriented

5 Results

5.1 Perceptions of Elementary School Students towards Socioscientific Issues

Students' perceptions towards socioscientific issues before participating in the simulation game are summarized in Table 4.

Table 4: Perception Pretest

	Support	Opposition
Issue 1: Coral Reefs	19 (83%)	4 (17%)
Issue 2: Plastic Waste	22 (96%)	1 (9%)
Issue 3: Coal Power	5 (22%)	18 (78%)
Issue 4: Anti-air Pollution	16 (70%)	7 (30%)
Issue 5: Refinery	14 (61%)	9 (39%)

From the results, it can be observed that the majority of students prefer to choose a stance that supports environmental sustainability (provide data). Students demonstrate an understanding of

the impact of human activities on the natural environment and tend to support measures that can reduce negative impacts. This reflects the current emphasis on environmental awareness in education and students' concern for ecological conservation.

In Issue 1 (relocation of natural gas receiving stations away from coral reefs coast, 19 support, 4 oppose) and Issue 2 (plastic waste, 22 support, 1 oppose), the vast majority of students chose options that support environmental sustainability, indicating that their emphasis on ecological conservation outweighs considerations for economic development. Similarly, in Issue 3 (coal-fired power generation, 5 support, 18 oppose) and Issue 4 (anti-air pollution, 16 support, 7 oppose), most students oppose the use of highly polluting energy sources and support measures to improve air quality.

The results of Issue 5 (the problem of CPC Kaohsiung refinery, 14 support, 9 oppose) show greater divergence of opinions, which may reflect uncertainty among students when balancing environmental and economic considerations. Nevertheless, the majority of students still chose to support the closure of the refinery.

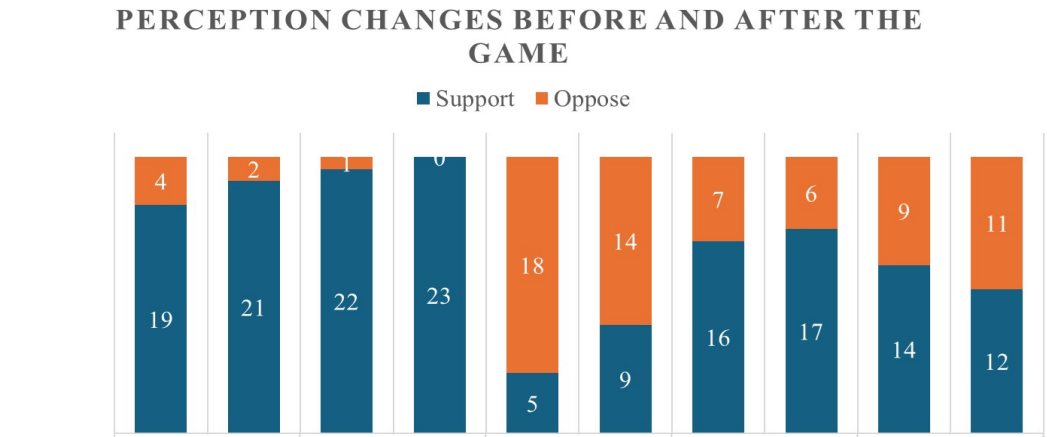
5.2 Perceptions of Students towards Socioscientific Issues - Changes After the Game

Students' perceptions after participating in the simulation game are shown in Table 5.

Table 5: Perception Pretest

	Support	Opposition
Issue 1: Coral Reefs	21(91%)	2(9%)
Issue 2: Plastic Waste	23(100%)	0(0%)
Issue 3: Coal Power	9(40%)	14(60%)
Issue 4: Anti-air Pollution	17(74%)	6(26%)
Issue 5: Refinery	12(52%)	11(48%)

There have been certain changes in students' perceptions towards various environmental and energy-related issues. Particularly in the issue of plastic waste (ISSUE 2), the support rate among students increased from almost unanimous support before the simulation game (22 support, 1 oppose) to complete unanimity in support after the simulation game (23 support, 0 oppose), reflecting their consensus on reducing plastic usage and environmental awareness. Regarding the issue of relocating natural gas receiving stations (ISSUE 1), the level of support also increased (from 19 to 21), indicating a further strengthening of students' emphasis on environmental protection. However, on the issues of coal-fired power generation (ISSUE 3) and refinery pollution (ISSUE 5), students' opinions showed greater divergence. Especially in the issue of coal-fired power generation, both support and opposition votes changed (support increased from 5 to 9, opposition decreased from 18 to 14), which may reflect students' more complex and diverse views after understanding the importance of coal-fired power generation in terms of economy and energy supply. As for the issue of the refinery, the support for closure slightly decreased (from 14 to 12), while opposition to closure increased (from 9 to 11), indicating that students' opinions became more balanced when exploring the trade-offs between economic interests and environmental impacts. The overall changes are illustrated in Figure 4 below.



	Issue1		Issue2		Issue3		Issue4		Issue5	
	pretest	posttest	pretest	posttest	pretest	posttest	pretest	posttest	pretest	posttest
Oppose	4	2	1	0	18	14	7	6	9	11
Support	19	21	22	23	5	9	16	17	14	12

Figure 4: Changes in students' perceptions

6 Conclusion

This study investigated the impact of role-playing mechanism and inquiry-based learning structure on elementary school students' perceptions towards socioscientific issues through the <Future City> simulation game. The results indicate that students' perspectives shifted after participating in the game, highlighting the educational potential of immersive role-playing in shaping students' understanding and perceptions towards complex societal challenges. Analysis of pre- and post-game questionnaire responses regarding students' perceptions suggests a general trend of enhanced support for environmental sustainability. This shift is particularly evident in specific issues, such as plastic waste management and the relocation of natural gas facilities, where perceptions after the simulation game demonstrate increased support for environmentally friendly options. However, on certain issues, such as coal-fired power generation and refinery pollution, students' opinions show greater divergence. This suggests that students hold more complex and diverse views after understanding the importance of coal-fired power generation in terms of economy and energy supply, including considerations of various factors. Additionally, regarding how to strike a balance between economic development and environmental protection, students exhibit more balanced opinions, reflecting the effectiveness of role-playing activities in enhancing students' understanding of the multifaceted nature of socioscientific issues.

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