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Fostering Inquiry Confidence in Elementary Students through a Game-Based Socioscientific Issue Learning Approach

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Abstract

This research aims to examine how the inquiry-based game Future City influences elementary students' confidence in their inquiry skills within the framework of a progressive inquiry learning model. The study was conducted at a public elementary school in Taiwan, where data were collected through pre- and post-assessments administered to sixth-grade students. During the game, players assumed various societal roles, engaged in interactive decision-making, and explored topics such as environmental sustainability, economic growth, and social equity. The key findings reveal that, after participating in the Future City game, students exhibited a notable increase in confidence regarding their inquiry abilities—particularly in drawing conclusions. Additional skills, including formulating questions, planning data collection, and reporting findings, also showed a modest improvement in confidence.

Keywords: Socioscientific Issue (SSI), Inquiry-based Game (IBG), Role-Play

1 Introduction

Facing the increasingly severe global challenges of the 21st century, including climate change, social inequality, and issues of technological ethics, people's expectations of education continue to rise. There is a growing demand for education to cultivate a new generation of citizens with critical thinking skills and the ability to approach problem-solving from multiple perspectives. Introducing citizens to real-world social science issues at an early stage helps develop their empathy, curiosity, and readiness for civic participation. In Taiwan, with rapid urban development and the concurrent environmental pressures, it is particularly important to foster students' sensitivity to social phenomena and their ability to take action based on inquiry.

To respond to this educational need, this study designed a teaching activity that combines role-playing with inquiry-based learning. The aim is to guide elementary school students through an immersive and interactive learning process, allowing them to explore complex social issues from the perspectives of various stakeholders. Through scenario simulations and multi-role interactions, the goal is for students to understand the conflicts and trade-offs inherent in these issues, analyze them from diverse perspectives, and deepen their understanding of social dynamics.

The contribution of this study lies in its innovative teaching method, which combines gamified

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learning with inquiry-based learning. By simulating real-world roles and situations, students are able to experience and analyze social problems from multiple angles. The study adopted a progressive inquiry design, from structure and guidance to final open-ended inquiry, aiming to cultivate and enhance elementary students' abilities and confidence throughout the inquiry process. This study mainly analyzes how students' confidence in their ability to engage in self-directed inquiry changes before and after participating in the inquiry-based game <Future City>.

2 Related Works

2.1 Socioscientific Issues

The study of socioscientific issues (SSIs) has become a key focus in science education, aiming to prepare students for complex societal challenges that require both scientific knowledge and ethical reasoning [1]. Recent research highlights the growing importance of SSIs in promoting scientific literacy, critical thinking, and ethical reflection among students [2].

One study explored the impact of SSI-based teaching on students' attitudes toward science and societal issues. It found that SSI instruction not only increases engagement with real-world problems but also encourages exploration of the social aspects of science. Additionally, students' prior knowledge and values were found to influence their responses to SSI lessons, suggesting that tailoring instruction to students' backgrounds can enhance its effectiveness [3]. Another review focused on the role of SSIs in fostering character and values. The study emphasized that SSIs are not just a tool for teaching science but also for developing ethical reasoning and moral judgment. It found that SSI-based instruction can improve decision-making and awareness of the ethical dimensions of scientific advancements, supporting students in becoming responsible citizens [4]. Tang, Lin and Hsu [5] used a co-word analysis of recent SSI research revealed its growing interdisciplinary nature, incorporating insights from ethics, politics, and environmental studies. This broadens the view of how SSIs are becoming integral to global education curricula. Research shows that SSIs help balance scientific inquiry with societal concerns, promoting a holistic approach to science education. In disaster preparedness and risk reduction, SSIs have proven effective in teaching students to apply scientific knowledge to real-world situations, such as natural disasters. By discussing environmental risks and societal impacts, SSI-based education enhances students' ability to navigate complex issues while improving science achievement, especially in areas like disaster preparedness and sustainability [6]. Their study showed that SSIs are particularly effective in contexts where students must apply scientific knowledge to real-world scenarios, such as in the case of natural disasters. By engaging students in discussions about environmental risks, societal impacts, and scientific solutions, SSI-based education helps students become more adept at navigating the complexities of such issues. The authors also highlighted how SSI-based instruction can enhance students' science achievement, particularly in areas related to disaster preparedness and environmental sustainability.

2.2 Inquiry Based Game

Inquiry-based learning (IBL) is a student-centered pedagogical framework that encourages learners to actively investigate authentic questions, construct knowledge through experiential processes, and develop higher-order thinking skills [7]. By shifting the instructional focus from passive content delivery to active problem-solving and exploration, IBL fosters autonomy,

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curiosity, and a deeper conceptual understanding of complex topics [8]. In recent years, scholars have increasingly turned to digital and analog games as powerful vehicles for facilitating inquiry, leading to the emergence of the inquiry-based game (IBG) as an innovative instructional tool. Games, by design, inherently encourage exploration, decision-making, and iterative problem-solving—qualities that align closely with the principles of IBL [9].

Numerous empirical studies have demonstrated the effectiveness of integrating IBL with game-based learning across various subject areas. An inquiry-driven microbiology game where students identified microbial infections through simulated clinical reasoning [10]. Their findings highlighted increased student engagement, content mastery, and collaborative inquiry. In science education, a phonomyography study on teachers using serious games to guide students through scientific inquiry processes has found that games enabled teachers to scaffold authentic learning environments, where students could hypothesize, investigate, and reflect—mirroring real-world scientific practices [11]. Similarly, a game blending virtual gameplay with physical science experiments was associated with improved cognitive and social engagement, as well as long-term retention of scientific knowledge among high school learners [12].

In the field of history education, the digital history game was implemented in fourth-grade classrooms, where students engaged in evidence-based reasoning, source analysis, and historical argumentation [13]. Their taxonomy of game-based historical inquiry showed how such games could scaffold complex disciplinary thinking in young learners. Moreover, a ubiquitous inquiry-based gaming model improved students' learning outcomes, motivation, and critical thinking abilities by integrating mobile learning with game mechanics [14]. Expanding into emerging technologies, a metaverse-enhanced IBL platform that fosters empathy and digital literacy through interactive, game-like tasks in virtual environments [15]. Their study revealed that immersive simulations can enhance both cognitive and socio-emotional competencies by situating learners in realistic, multi-perspective scenarios.

These diverse implementations collectively illustrate the potential of inquiry-based games to transform traditional instruction into dynamic, learner-driven experiences. By merging the motivational affordances of games with the epistemic richness of inquiry, educators can create learning environments that promote exploration, resilience, and interdisciplinary problem-solving.

3 Activity Design

The game <Future City> is an extension of the game <City Auncel>[16]. The overall planning of the activity is based on three core axes: Inquiry of Socio-Science Issues, Role-Playing, and the <Future City> System. The story was surrounded by an endangered endemic species of Taiwan, the Leopard cats, which has long faced threats from habitat fragmentation and human development activities. This issue not only intertwines ecological and social aspects but also encompasses multiple layers, including government policy, public life, and land ethics, making it an ideal field for issue-oriented learning. Therefore, the inquiry-based game aims to enable students to make strategic choices and engage in systematic reflection through diverse role settings.

3.1 Inquiry Framework for Socioscientific Issues

This game centers around the "Survival of the Taiwan Miaoli Leopard Cat" issue and utilizes a systematic design of the inquiry process, integrating digital system operations and role-playing

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strategies. The objective is to gradually deepen players' understanding of the tension between environmental conservation and social development through multiple rounds of interaction and negotiation. The game is not a one-time task but follows a progressive, open-ended structure, guiding players from structured understanding to self-driven questioning and the creation of integrated solutions. This approach focuses on skill development throughout the gameplay. The game is divided into three stages: Structured Inquiry and Role Understanding, Guided Inquiry and Issue Deepening, and Open Inquiry and Solution Proposal.

1. Stage One: Structured Inquiry. The core objective of this stage is to encourage players to start thinking about the issue and propose hypotheses. These hypotheses are primarily based on the players' initial understanding of the topic, and the correctness of these hypotheses is not evaluated at this stage. Instead, the main goal is for students to recognize the diversity and complexity of the problem and begin to develop a preliminary understanding of the issue. At the same time, students learn how to use data provided by the system to conduct research and analysis, helping them engage in more organized inquiry during subsequent stages. The design of this stage not only encourages players to pose questions but also assists them in learning how to gather relevant information to support or challenge their hypothesis.

2. Stage Two: Guided Inquiry. In this stage, the players' inquiry is further refined. The guided inquiry approach helps narrow their research scope, shifting them from simply posing questions to actively verifying and analyzing their hypotheses. During this stage, players take on specific roles, and these roles influence their choices and thought processes. For example, if players assume the roles of conservation organizations or farmers, they may focus on analyzing the impact of land development on the Leopard cat's habitat. On the other hand, if they take on the roles of developers or government officials, their inquiry might center around development and economic benefits, with the main discussion revolving around balancing development with conservation needs. The guided inquiry design enables players to delve more specifically into the issue, enhancing their understanding. In this round, players not only answer the questions posed earlier but also use their role-specific knowledge to select relevant data and reconsider potential solutions.

3. Stage Three: Open Inquiry. By the third round, players' inquiry enters the most challenging and autonomous phase. In this round, players are no longer limited to the problems provided by the system or the teacher. Instead, they begin to define their own questions and plan the inquiry process. At this stage, players are free to choose issues they are particularly interested in. They might focus on more complex and integrated problems, such as how to design a feasible ecological corridor to protect leopards cat's migration routes, or how to balance development demands with ecological protection in urban planning. The design of this stage requires players to consider various factors comprehensively and choose data sources that support their viewpoints. For example, players may explore issues from perspectives such as water resources, land use, and wildlife conservation, using various data to drive the formation of solutions.

3.2 Inquiry Data Design

The data is divided into four categories: water resource data, land use data, animal conservation data, and population structure data. Water resource data primarily focuses on water quality indicators such as the river pollution index, pH value, minerals, heavy metals, and dissolved oxygen levels, helping players understand the water quality status of specific rivers and analyze whether it exceeds permissible limits. Land use data provides information on the land use patterns in different regions of Miaoli, including agricultural land, construction land, and forest land, allowing players to understand land development trends and their potential impacts on natural

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habitats and species survival. Animal conservation data includes information on the leopard cat's activity range, sighting locations, and roadkill records, helping players analyze the leopard cat's habitat and survival situation, and understand the relationship between the local environment and biodiversity. Population structure data provides information on population changes, age distribution, and urbanization levels in Miaoli area, allowing players to observe population trends and analyze their impact on local development demands and land use. For instance, rapidly growing populations in certain areas may indicate higher development pressure, potentially affecting the local ecological environment.

When students analyze single data points, they may validate more direct and straightforward questions, such as checking whether a river meets water quality standards through water quality indicators. This is a relatively simple and clear issue. However, when students overlay data from different perspectives, they begin to confront more complex problems. For example, when students combine water quality data, land use data, animal conservation data, and population structure data, they might encounter the following complex issues:

Suppose students observe that a particular area's water quality indicators show severe pollution, especially with high levels of heavy metals. This might be linked to changes in land use in the area, particularly the conversion of agricultural land into construction land. They might also notice that these changes are occurring in regions where the leopard cat is active, and that the population in these areas is growing rapidly, leading to increased construction demand. Students might hypothesize that these interconnected factors are exacerbating water pollution, disrupting the leopard cat's habitat, and even increasing the risk of roadkill. This is not just an issue of a single water quality indicator but a multifaceted challenge involving land development, species conservation, and population growth.

3.3 Game Design

In the design of Future City, character design is a key element that supports both the learning process and situational inquiry. Centered around the leopard cat crisis, the characters help players understand the conflicts and cooperation among various social interest groups, highlighting the balance between urban development and environmental conservation. Five roles are featured—Government, Conservation Group, Developer, Farmer, and Hunter—each representing a stakeholder in the issue. With unique goals and responsibilities, these roles interact through both conflict and collaboration to achieve a shared objective: balancing national development with ecological protection.

1. Government: The government's main objective is to promote national development while maintaining public support, which is crucial for political stability. At the same time, the government must balance economic growth with environmental protection by keeping both the national development index and environmental conservation index at appropriate levels. Through policy decisions, the government can adjust these indices and influence other stakeholder behaviors. Key metrics for the government include the national development index, public satisfaction, and financial status, all of which are impacted by how well its policies align with the interests of the majority.

2. Conservation Group: The conservation group aims to strengthen environmental protection and collaborate with the government to ensure effective ecological conservation. It influences government and developer actions by advocating for conservation policies, reviewing development plans, and offering ecological guidance. The conservation group is evaluated through the environmental conservation index and public opinion, with its satisfaction depending on the success of environmental efforts and the government's responsiveness to conservation

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measures.

3. Developer: The developer’s main goal is to drive national economic growth and personal profit by promoting construction, particularly urban expansion. However, they must also balance economic interests with environmental protection, especially considering ecological needs in development. The developer’s key metrics include the environmental conservation index, financial status, and public opinion, which determine the success of their projects and profitability.

4. Farmer: The farmer focuses on increasing agricultural output and maintaining steady income, but faces environmental challenges, such as invasive species. Their actions impact both food supply and the environment, particularly through pesticide use, which may lead to public dissatisfaction. The farmer’s metrics include agricultural yield, financial status, and public opinion, which affect their livelihood and perception of government policies.

5. Hunter: The hunter’s goal is to increase the yield from hunting to secure income. However, their activities often conflict with conservation efforts, especially when hunting endangered species like the leopard cat, which jeopardizes the species' survival. The hunter’s metrics include hunting yield, financial status, and public opinion, reflecting the impact of their actions on wildlife conservation.

3.4 Game Mission Objectives

Mission objectives in the context of this inquiry-based game are designed to guide the players' decision-making process and enhance their engagement in the role-playing experience. These objectives are divided into two primary components: personal missions, and common goals shown in (Table1).

Table 1: Game Mission

Role Category	Role	Personal Missions	Common Goal
Neutral Party	Government	1、Government Satisfaction > 60% 2、At least 1 public project	Environmental Conservation Index > 60% National Development Index > 60%
Conservation Group	Conservation Group	1、Environmental Conservation Index > 70% 2、At least 1 environmental project	
Development Group	Developer	1、Money > 600 2、At least 1 building project	
Livelihood Group	Farmer	1、Agricultural Output > 300 2、Money>200	
	Hunter	1、Hunting Yield > 300 2、Money>200	

Personal Missions

Each character is given specific personal missions that drive their behavior within the game. These missions are aligned with the character's goals and values, ensuring that their actions in the game are consistent with their role. For example:

- The Government has the mission to achieve a Government Satisfaction score greater than 60% and implement at least one public project. This aligns with their responsibility to balance development with public support.

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- The Conservation Group aims to raise the Environmental Conservation Index above 70% and ensure at least one environmental protection initiative is enacted, aligning with their core mission of environmental sustainability.
- The Developer is tasked with ensuring the National Development Index increases while earning at least 600 units of money and completing one building project, representing their role in economic growth and urban development.
- The Farmer focuses on increasing Agricultural Output to over 300 units and earning at least 200 units of money, reflecting the need to sustain agricultural production and financial stability.
- The Hunter must increase Hunting Yield to over 300 units while ensuring their income reaches at least 200 units, reflecting the need for a sustainable hunting practice while also maintaining their livelihood.

These personal missions are carefully crafted to align with the character's core values and provide them with a clear direction to guide their actions during the game.

Common Goals

In addition to personal missions, common goals are integrated to deepen the interactions between characters and encourage collaboration and negotiation. The common objectives are designed to bring the characters together by highlighting shared challenges and aspirations. The common goals are:

National Development: Achieving a balance between National Development Index and Environmental Conservation Index is a critical shared objective. In order to succeed, both indices must exceed 60%.

Environmental Sustainability: The preservation of the environment is another common goal that transcends individual roles. All characters, even those focused on development or economic growth, must ensure that the Environmental Conservation Index reaches above 60% to demonstrate a commitment to sustainability.

The common goals serve as a bridge between characters, encouraging them to collaborate and negotiate to find solutions that balance economic development and environmental conservation. By achieving these shared objectives, players experience firsthand the complexity of balancing growth and sustainability, reinforcing the importance of considering multiple perspectives in decision-making processes.

4 Research Method

4.1 Research Design

This study adopts a pre-experimental research design to explore whether role-playing and the inquiry-based game <Future City> have an impact on elementary school students' confidence in their inquiry abilities. Prior to the experiment, all students will complete a pre-test questionnaire to assess their confidence in inquiry abilities and behaviors related to inquiry-based learning before participating in the game. Subsequently, students will participate in the <Future City> inquiry-based game. After the experiment, students will complete the confidence questionnaire on inquiry abilities and behaviors once again to evaluate changes in their confidence in their inquiry abilities during the inquiry learning process.

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4.2 Participants

This study was conducted in a public elementary school in Taiwan, targeting sixth-grade students. A total of 23 students participated, including 11 males and 12 females. The game lasted approximately two hours. Students were grouped according to their regular class division, and due to the game mechanics, the 23 students were randomly assigned to four groups: one group of 5 students and three groups of 6 students.
The game <Future City>, which combines role-playing and inquiry-based learning, served as the main activity for this research. The detailed process of the research is outlined in Figure 1. To ensure smooth gameplay, the researchers collaborated with the classroom teacher to manage and control any unexpected behaviors that may arise during the game.

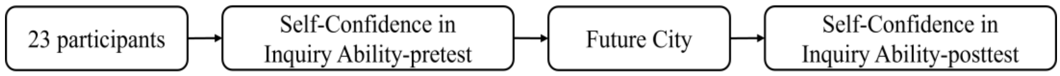

Figure 1: Research Process

4.3 Research Tools

This study uses the Self-Confidence in Inquiry Ability Questionnaire to explore changes in players' confidence in their inquiry learning abilities before and after participating in inquiry activities. The questionnaire is designed based on the five stages of inquiry learning and is aligned with the National Science Education Standards [17] to define the scope of players' inquiry-related skills and their confidence in applying them. Comprising 18 questions divided into five dimensions, each dimension assesses players' confidence in different abilities during the inquiry process (Table 2). The main purpose is to analyze the changes in players' confidence in mastering and applying inquiry skills throughout the learning process.

1. Formulating Questions (4 questions). This section aims to assess students' confidence in their ability to generate interest and identify meaningful questions when encountering natural phenomena or social science issues. The questions focus on how confident students feel about organizing and classifying information after observations, discovering relevant problems, and forming hypotheses or assumptions regarding those problems.

2. Planning Data Collection Process (4 questions). This section evaluates students' confidence in planning appropriate strategies for data collection during the inquiry process. It includes their confidence in selecting suitable data sources, determining effective ways to collect and process the data, and using the data to formulate hypotheses that address the research questions.

3. Execution (3 questions). In the execution phase, the questions are designed to assess students' confidence in their ability to filter and utilize valuable data. This includes how confident they feel about observing systematically using their senses and various tools, accurately recording findings, and managing tasks during the inquiry process.

4. Forming Conclusions (3 questions). This section measures students' confidence in analyzing and interpreting data to draw logical conclusions. The focus is on how sure they are about summarizing results, explaining observed phenomena, and making predictions based on the data.

5. Reporting (4 questions). The final section focuses on students' confidence in communicating their inquiry process and findings. It assesses how confident they feel about expressing their results through writing, speaking, and visual representations (e.g., charts), as well as responding to feedback and engaging in self-reflection.

The questionnaire in this study used a five-point Likert scale to assess participants' agreement

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with statements, allowing for the quantification of changes in confidence regarding their inquiry abilities. Its reliability, measured with Cronbach's alpha (0.884), indicates high internal consistency. Due to the non-normal distribution of the sample data, the Wilcoxon signed rank test was used for statistical analysis, providing an accurate assessment of changes in students' self-confidence in inquiry ability before and after the learning activity.

Table 2: Self-Confidence in Inquiry Ability Questionnaire

Dimension	Number of Questions	Main Evaluation and Analysis Content
Formulating Questions	4	Assesses students' confidence in generating meaningful questions, organizing observations, and forming hypotheses.
Planning Data Collection	4	Evaluates students' confidence in selecting data sources, planning data collection, and formulating hypotheses.
Execution	3	Measures students' confidence in observing systematically, recording data accurately, and managing tasks.
Forming Conclusions	3	Assesses students' confidence in analyzing data, drawing conclusions, and making predictions.
Reporting	4	Evaluates students' confidence in communicating findings through writing, speaking, and visual representations, as well as responding to feedback.

5 Results

The research results are shown in the Table 3. In terms of the Forming Conclusions dimension. The pre-test mean score was 3.32(SD = 0.51), which increased to 3.71 (SD = 0.63) in the post-test. The statistical analysis yielded a z-value of -3.18with a p-value of .001, indicating a highly significant level of improvement ($p < .01$). Students experienced significant growth in their confidence to interpret data and derive reasonable conclusions. This improvement likely stemmed from the data analysis tasks integrated into the inquiry-based game, where students had to work with diverse sets of clues and evidence. The game's design appears to have fostered this confidence-building, as students practiced reasoning and decision-making, which is a key component of drawing conclusions.

In contrast, the Execution dimension demonstrated the least growth in students' confidence, with a marginal increase in mean score from 3.67 (SD = 0.80) to 3.72 (SD = 0.51), with a z-value of -0.83 and a p-value of .417. Despite students' theoretical understanding, they struggled with the practical aspects of executing their plans, likely due to factors like operational complexity, time constraints, or information overload. The observation that students often sought approval before proceeding suggests they lacked the confidence to execute their plans independently. This indicates that more hands-on guidance and practical support during implementation could be vital to fostering greater self-reliance in executing tasks.

The Formulating Questions dimension showed an increase in confidence, although it did not reach statistical significance. This suggests that while students became more adept at observing phenomena and generating research questions, the growth in this area was not as pronounced as in other dimensions. One possible explanation for this is that the activities related to question formulation were somewhat indirect within the overall inquiry-based game design. Students may

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have been prompted to develop questions based on observations, but without specific exercises or dedicated instruction focused on how to form precise and effective research questions, their progress may have been slower. Similarly, the Planning for Data Collection dimension saw a slight increase in confidence, but challenges in independently creating data collection plans remained evident. In particular, many students exhibited hesitation and uncertainty when it came to designing their own data collection strategies during the later stages of the inquiry process. Although they could follow a structured framework when given one, they struggled with the more open-ended aspects of planning, which involved determining what data was necessary, how to collect it, and how to ensure the process was rigorous.

Lastly, in the Reporting dimension, there was an increase in standard deviation, which indicates a disparity in students' confidence levels, with some gaining confidence while others faced challenges, possibly due to anxiety or lack of support in public speaking. This suggests that additional support for reporting and presentation skills could help alleviate these disparities and boost overall confidence in this area.

In terms of overall performance across all constructs, the total mean score improved from 3.55 (SD = 0.45) in the pre-test to 3.74 (SD = 0.50) in the post-test. The z-value of -2.6 and corresponding *p*-value of .01 indicate a statistically significant improvement ($p < .05$). This result suggests that the inquiry-based, game-based learning approach had a meaningful impact on students' overall confidence and competence in the inquiry process.

Table 3: Pre- and post-assessment of students' self-confidence in inquiry skills

Construct	*N*	***Mean (SD)***		*df*	*z-value*	*p*
		Pre-test	**Post-test**			
Formulating Questions	21	3.62 (0.43)	3.80 (0.60)	20	−1.22	0.227
Planning Data Collection	21	3.52 (0.62)	3.74 (0.62)	20	−1.19	0.236
Execution	21	3.67 (0.80)	3.72 (0.51)	20	−0.83	0.417
Forming Conclusions	21	3.32 (0.51)	3.71 (0.63)	20	−3.18**	0.001
Reporting	21	3.54 (0.48)	3.74 (0.62)	20	−1.44	0.149
Total	21	3.55 (0.45)	3.74 (0.50)	20	−2.6*	0.01

p<.05*, p<.01**

6 Conclusion

This study examined how the inquiry-based game <Future City> influenced elementary school students' confidence in their own inquiry abilities when engaging with socioscientific issues. Rather than aiming to improve actual inquiry skills, the focus was on students' self-perception of their ability to participate in the inquiry process. The results showed a significant increase in students' overall confidence, especially in forming conclusions. The game's structured design, which involved analyzing diverse data and making decisions from multiple stakeholder perspectives, likely gave students repeated opportunities to build trust in their reasoning and judgment. They began to see themselves as capable of making sense of complex information.

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Other dimensions, like formulating questions and planning data collection, showed only slight improvement. This suggests students were still uncertain in more open-ended phases of inquiry, especially when required to initiate tasks independently. The slight drop in execution confidence also highlights the challenge students faced in applying their plans without external guidance, pointing to a need for more support when transitioning from structured to autonomous inquiry. In sum, the game effectively enhanced students' confidence in participating in inquiry, particularly in drawing conclusions. However, further support is needed to help students feel equally confident in the earlier and more autonomous stages of inquiry, ensuring a more balanced development of self-assurance across the full inquiry process.

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