Development of Environmental Literacy through the Process of Board Game in Primary Schools based on Chiang Mai's Urban Context

Omsin Jatuporn[1*], Piyachai Nakon[2]

[1*]Department of Educational Foundations and Development, Research Center for Multiculturalism and Education Policy, Multidisciplinary Research Institute, Chiang Mai University, Thailand
[2]Office of Research Administration, Chiang Mai University, Research Center for Multiculturalism and Education Policy, Multidisciplinary Research Institute, Chiang Mai University, Thailand

ABSTRACT

Background and Objectives: This research aims to: 1) explore the spatial context, dynamics, and interrelationships between ecological, social, cultural, political, historical, and technological systems in the Ping River Basin; 2) design and develop a board game for enhancing environmental literacy in primary schools using Chiang Mai's urban context; and 3) investigate the effects of the developed board game on primary school students' environmental literacy in terms of knowledge, attitudes, and environmental conservation behaviors.

Methodology: The study employed a research and development methodology across three phases. Phase 1 explored the Ping River Basin context through document analysis, in-depth interviews with 18 key informants (academics, government specialists, local knowledge holders, and civil society representatives), and field surveys documenting physical characteristics and community activities. Phase 2 involved developing the "Ping River Guardians" board game based on the findings from Phase 1, followed by quality assessment conducted by 11 experts (game designers, environmental educators, and teachers) and pilot testing with 30 students. In Phase 3, researchers implemented the refined game with 90 students from grades 4–6 selected through multistage random sampling across three schools, using a one-group pretest–posttestdesign over 12 weeks, with data collected through environmental literacy tests, attitude scales, behavior assessments, and observation forms.

Results: The contextual analysis revealed rich natureculture relationships in the Ping River Basin manifesting through traditional ecological knowledge systems, cultural practices, and collective resource management structures. Specific findings included seven distinct water - knowledge states identified by local elders, river ceremonies dating back 700 years, and community-based adaptations combining traditional knowledge with modern approaches. The Ping River Guardians board game, developed with visual representations of local ecosystems,

ARTICLE INFO

Article history:
Received 15 April 2025
Revised 29 May 2026
Accepted 9 June 2026

Keywords:
Environmental literacy, Game-based learning, Natureculture relations, Place-based education, Traditional ecological knowledge

collaborative mechanics, and culturally relevant scenarios, received high-quality ratings from experts (content validity IOC = 0.87; game mechanics rating 4.52/5.00). The implementation resulted in statistically significant improvements in environmental knowledge ($t = 15.28$, $p < .001$; + 49.9%), attitudes ($Z = 7.42$, $p < .001$; +32.9%), and conservation behaviors ($t = 12.64$, $p < .001$; +75.1%). The most substantial improvements occurred in waste reduction practices (+85%), water conservation behaviors (+72%), community participation (+63%), and family knowledge sharing (+68%).

Discussion: The study demonstrates that board games incorporating local natureculture relationships can effectively enhance environmental literacy by positioning humans as "a part of" rather than "apart from" natural systems. The game successfully bridged the "extinction of experience" (Soga & Gaston, 2016) by creating rehearsal spaces (Lynch & Mannion, 2021) where students developed systems thinking while connecting abstract concepts to local contexts. By integrating human activity, knowledge systems, power dynamics, cognitive development, and culturally responsive learning, the approach addresses multiple dimensions of nature-culture relations identified by the Learning in Places Collaborative (2020).

Conclusion: While acknowledging limitations of the one-group design and 12-week implementation period, the findings provide empirical evidence for integrating traditional ecological knowledge with modern educational approaches. The results suggest that place-based board games offer a promising pathway for developing the environmental literacy needed to address sustainability challenges while strengthening students' connections to local ecological and cultural heritage.

*Corresponding author
E-mail address: omsin.j@cmu.ac.th

Introduction

Chiang Mai province is experiencing increasingly severe environmental crises, particularly in urban areas. Air pollution has emerged as one of the most critical challenges, with particulate matter (PM 2.5) levels reaching 200 micrograms per cubic meter in 2023 – four times the standard limit – resulting in over 60 days of hazardous air quality (Pollution Control Department, 2024). The Ping River ecosystem faces significant degradation, with dissolved oxygen levels below 2 mg/L and fecal coliform contamination exceeding standards by five times. Additionally, the city handles 320–340 tons of waste daily, exacerbated by the proliferation of buffet-style restaurants generating substantial food waste. These interconnected challenges

affect not only ecosystem health but also local economies, political dynamics, and cultural practices of riverside communities.

Environmental education has evolved significantly in recent decades, shifting from purely scientific approaches to more integrated methods that recognize the interconnectedness of natural and social systems. Mannion et al. (2013) and Somerville (2013) emphasize that traditional classroom instruction often fails to create meaningful connections between theoretical knowledge and real-world environmental challenges. Environmental literacy encompasses multiple dimensions: knowledge of ecological principles, analytical skills for environmental issues, problem-solving abilities, the development of pro-environmental attitudes, and the capacity for civic engagement (Ito & Igano, 2020; Molina-Motos, 2019).

The natureculture concept, introduced by Haraway (2018) and developed by scholars such as Tsing (2015) and Latour (2005), provides a valuable theoretical framework that challenges the traditional nature-culture dichotomy. This perspective recognizes that environmental challenges require understanding the complex interplay between ecological systems and human cultural practices (Greenwood, 2017). In this light, the Ping River communities exemplify this natureculture relationship through sophisticated traditional knowledge systems, including water-level observation techniques, the use of indicator species for environmental monitoring, and sustainable irrigation practices. Cultural dimensions thus manifest through river blessing ceremonies "*Sueb Chata Mae Nam*" and forest ordination rituals that integrate spiritual practices with conservation objectives. The traditional Muang-Fai irrigation system also demonstrates how communities have established collective governance structures that blend physical infrastructure with sophisticated social arrangements for resource management (Department of Water Resources, 2009; Ponrach, 2013).

Educational research demonstrates that board games offer strong pedagogical potential, particularly for understanding complex systems. Through strategic gameplay, students develop systems-thinking abilities as they recognize patterns, understand interconnections, and anticipate consequences of decisions. Board games provide immediate feedback, allowing students to refine problem-solving strategies through experimentation. The collaborative nature of board games fosters communication and social skills development as students articulate thoughts, negotiate with others, and work together toward objectives. In environmental education specifically, board games simulate environmental systems in ways that make abstract concepts tangible, demonstrate cause-effect relationships, and create safe spaces for exploring different management strategies without real-world consequences (Shimabukuro et al., 2022).

The growing disconnects between children and natural environments, what Soga and Gaston (2016) describe as the "extinction of experience," is particularly concerning in urban settings. Current environmental education approaches often position nature as a resource to be managed rather than a system with which humans have reciprocal relationships. School curriculum analysis reveals predominantly human-centric approaches with limited integration of traditional ecological knowledge. This research aims to address these gaps by harnessing nature culture perspectives in developing innovative approaches to environmental education.

By exploring the spatial context of the Ping River Basin, developing an educational board game, and evaluating its effectiveness, this study seeks to bridge traditional ecological knowledge with modern educational approaches. The board game approach itself reflects natureculture integration by creating a learning environment where students engage with both ecological principles and cultural practices simultaneously (Boivin, 2020). This approach moves

beyond traditional environmental education paradigms that separate natural and cultural systems, instead offering a more integrated understanding that reflects the actual complexity of environmental challenges in urban contexts such as Chiang Mai (Jatuporn, 2025).

The study pursues three main objectives: 1) to investigate the spatial context, dynamics, and relationships between ecological, social, cultural, political, historical, and technological systems in the Ping River Basin, 2) to design and develop a board game for enhancing environmental literacy in primary schools using Chiang Mai's urban context, and 3) to evaluate the effects of the developed board game on primary school students' environmental literacy regarding knowledge, attitudes, and conservation behaviors.

This research makes a significant contribution to the field by providing robust empirical evidence for the effectiveness of integrating traditional ecological knowledge with modern educational approaches through game-based learning. By positioning humans as "a part of" rather than "apart from" natural systems, the board game challenged conventional human-centric approaches to environmental education while honoring indigenous ways of knowing that have sustained ecological relationships for generations. The study's findings reinforce the importance of place-based learning that recognizes the environmental knowledge embedded within local cultural practices and resource management systems (Ito & Igano, 2020).

As environmental education evolves to address growing ecological challenges, approaches integrating cultural dimensions with ecological understanding become increasingly vital. The "Ping River Guardians" board game exemplifies how educational tools can simultaneously address multiple dimensions of nature-culture relations: human activity through collaborative decision-making, knowledge systems through traditional practices, power dynamics by challenging dominant narratives, cognitive development through systems-thinking, and learning environments through culturally relevant contexts. By connecting classroom education with community experiences, such approaches create pathways for students to translate environmental concepts into concrete actions (Duhn et al., 2017; Goodlad & Leonard, 2018). Educational resources designed with attention to natureculture relationships offer promising opportunities for developing environmental literacy, while strengthening students' connections to their ecological and cultural heritage.

Methodology

This study employed a research and development approach with mixed-methods data collection, divided into three distinct phases aligned with the research objectives (Creswell, 2008). Phase 1 emphasized qualitative data collection through document analysis, in-depth interviews, and field surveys. Phase 2 focused on innovation development following the research and development process. Phase 3 employed a one-group pretest –posttest experimental design to examine the effectiveness of the developed board game.

This study was approved by the Chiang Mai University Research Ethics Committee (Certificate of Approval No. 124/67; Project Code CMUREC No. 67/182). The research protocols included obtaining informed consent from participants, ensuring confidentiality, and maintaining data security throughout the research process.

Research Procedures

Phase 1 Contextual Exploration: The first phase explored the spatial context, dynamics, and relationships between ecological, social, cultural, political, historical, and technological systems in the Ping River Basin. This phase involved the following activities:

1.1. Reviewing academic literature, research reports, theses, government documents, local records, historical photographs, and maps to analyze ecological systems and to synthesize local knowledge.

1.2. Conducting semi-structured interviews with 18 key informants, including university professors and academic experts (10), government specialists (2), local knowledge holders (3), and civil society representatives (3). Following established qualitative procedures (Buosonte, 2013), interviews were recorded, transcribed, and verified by the informants.

1.3. Examining designated areas along the Ping River in the urban areas of Chiang Mai, documenting physical and biological characteristics, observing community activities, and creating ecosystem and land-use maps.

Phase 2 Board Game Development: The second phase focused on designing and developing the board game for enhancing environmental literacy, following these steps:

2.1. Analyzing data from Phase 1 to determine game components; designing the game board to simulate local ecosystems; developing game mechanics and rules; creating situation cards and activities; and preparing teaching manuals.

2.2. Evaluating the prototype with 11 experts, including game-design specialists (3), environmental education experts (3), and primary school teachers (5).

2.3. Conducting pilot tests with 30 students who were not part of the sample, observing issues during gameplay, collecting feedback from players and teachers, and refining the game based on findings.

Phase 3 Implementation and Evaluation: The final phase investigated the effects of the developed board game on students' environmental literacy, following a one-group pretest – posttest experimental design. The phase included the following steps:

3.1. Obtaining institutional permissions, briefing teachers and students, gaining parental consent, and preparing research instruments.

3.2. Conducting a 12-week intervention with 90 students from grades 4 –6, selected through multistage random sampling from three schools. The implementation was structured as follows: game introduction and basic training (week 1); learning activities through the game (two periods per week, weeks 2–11); and summarizing and evaluating learning outcomes (week 12).

During weeks 2 –11, each session followed a three-part structure: (1) a brief warm-up discussion connecting prior game experiences to real-world environmental observations (10 minutes); (2) structured gameplay with scenario and action cards targeting specific environmental literacy dimensions — weeks 2–3 focused on Ping River Basin ecology, weeks 4–5 on traditional ecological knowledge and natureculture relationships, weeks 6–7 on environmental challenges and cause-effect analysis, weeks 8–9 on collaborative resource management, and weeks 10–11 on integrated multi-stakeholder scenarios (30–35 minutes); and (3) teacher-facilitated post-game reflection connecting in-game decisions to local environmental realities (10–15 minutes). The board game served as the central learning medium around which all instructional activities were organized, rather than functioning as a supplementary tool.

Data collection was administered through pretests and posttests measuring environmental literacy, attitudes, and conservation behaviors; conducting ongoing behavioral observations; and collecting additional qualitative data through interviews.

Sample and Key Informants

The research involved participant groups across the three phases.

Phase 1 included 18 key informants selected through purposive sampling, including university professors or academic experts, government specialists, local knowledge holders, and civil society representatives.

Phase 2 involved 11 experts for quality assessment, including game-design specialists, environmental-education experts, and primary-school teachers.

Phase 3 included 90 students from grades 4-6, obtained through multistage random sampling: first selecting three schools from 12 schools in the Chiang Mai Primary Educational Service Area Office 1, then randomly selecting two classrooms per school, and finally randomly selecting 15 students per classroom.

Research Instruments

The research employed multiple instruments across the three phases.

Phase 1 included a semi-structured interview guide covering key environmental and socio-cultural aspects, and a field-survey form for documenting ecosystem characteristics and community activities.

Phase 2 included the environmental-literacy board-game prototype and a quality-assessment form for expert evaluation.

Phase 3 included an environmental-literacy test covering knowledge, impact analysis, problem investigation, and participation; an environmental-conservation attitude scale; an environmental-behavior assessment form; and a behavioral-observation form for recording student interactions during gameplay.

Data Analysis

Data analysis methods varied according to the research phases.

Phase 1 involved content and thematic analysis of documents and interview transcripts (Patton, 2002), as well as systematic analysis of spatial data to create relationship maps showing interactions between ecosystems and community lifestyles.

Phase 2 involved analysis of expert evaluations using the Index of Item-Objective Congruence (IOC), calculation of means and standard deviations for quality assessment scores, and qualitative analysis of expert suggestions for game improvement.

Phase 3 involved escriptive statistics (frequency, percentage, mean, standard deviation); inferential statistics (paired t-test for environmental-literacy scores and the Wilcoxon signed-ranks test for attitude scores); qualitative analysis of observation records and interview data; and integrated mixed-methods analysis connecting quantitative and qualitative results.

Validity and Reliability

The research employed various validation strategies to ensure data quality.

Phase 1 involved triangulation methods (data, source, and methodological triangulation), member checking by returning analyzed data to interviewees, and expert-audit reviews.

Phase 2 included content-validity assessment by environmental-education experts, game- mechanism evaluation by game-design specialists, and feasibility assessment by primary-school teachers.

Phase 3 involved content-validity verification by experts (IOC); analysis of difficulty and discrimination indices from pilot testing; reliability testing using the KR-20 formula for objective tests and inter-rater reliability for subjective assessments; and calculation of Cronbach's alpha coefficients for attitude and behavior scales.

Findings

The findings of this research are presented according to the three research objectives: contextual exploration of the Ping River Basin, development of the environmental literacy board game, and evaluation of the game's effectiveness.

Spatial Context, Dynamics, and Relationships in The Ping River Basin

Ecological System and Environmental Dynamics

The analysis of documents, interviews, and field surveys revealed that the Ping River ecosystem in the urban areas of Chiang Mai is characterized by a complex interplay of natural and anthropogenic factors. The river basin features diverse micro-ecosystems, including riparian forests, wetlands, and traditional irrigation systems (Muang Fai) that support a variety of flora and fauna. These ecosystems function as integrated units, with seasonal variations creating dynamic shifts in ecological relationships throughout the year. Local biodiversity surveys identified more than 120 plant species and 85 animal species directly dependent on these river ecosystems, highlighting their ecological importance despite ongoing urbanization pressures.

Environmental monitoring data indicated significant challenges in the area, particularly regarding air quality deterioration, with PM2.5 levels reaching 200 $\mu g/m^3$ during critical periods - four times above the standard limit of 50 $\mu g/m^3$. This air quality crisis typically occurs between January and April, coinciding with agricultural burning practices and unfavorable meteorological conditions. In addition, water quality assessments revealed significant degradation, with dissolved oxygen levels below 2 mg/L in urban areas and fecal coliform contamination exceeding standards by a factor of five. Moreover, the municipal waste management system struggles with increasing solid waste generation, handling between 320-340 tons per day in Chiang Mai Municipality, with only limited recycling infrastructure. Additionally, hydrological data showed seasonal water level fluctuations with increasingly extreme patterns in recent years, featuring more severe flooding during the rainy season and prolonged drought during the dry season.

Key informants identified three main drivers of environmental degradation: (1) rapid urbanization and land-use changes, which reduced natural buffer zones and increased impervious surfaces, with urban areas along the Ping River expanding by 28% between 2010 – 2023; (2) climate change impacts altering rainfall patterns and temperatures, including a1.2°C increase over the past three decades, disrupting traditional agricultural calendars; and (3) intensified resource competition among agricultural, industrial, and service sectors, especially during dry seasons when tourism demand peaks alongside agricultural needs, triggering water allocation conflicts and governance challenges.

Natureculture Relationships

The study uncovered rich natureculture relationships in the Ping River communities, manifested through traditional ecological knowledge systems, cultural practices and beliefs, and social organization for resource management. In this context, local communities have developed sophisticated environmental monitoring practices that demonstrate deep understanding of ecological processes. These practices include water-level observation techniques to predict seasonal changes and potential flooding. Community elders can interpret subtle changes in water color, sediment patterns, and flow characteristics to forecast weather conditions with remarkable accuracy.

Field observations documented how these knowledge holders identify at least seven distinct water states throughout the year, each associated with specific agricultural and community preparations. In addition, the use of specific plant and animal species as environmental quality indicators represents another dimension of this knowledge system. For instance, the presence of certain dragonfly species and aquatic plants serves as indicators of water quality, while the behavior of migratory birds provides cues about broader climatic patterns. Traditional irrigation management systems that balance water allocation among communities demonstrate adaptive management approaches that have evolved over centuries, with documented evidence of their resilience during historical droughts.

Cultural practices and beliefs in the region embed environmental stewardship within spiritual and social frameworks. These can be witnessed in the river-blessing ceremonies *Sueb Chata Mae Nam* , which coincide with critical ecological transitions and serve multiple functions in community environmental governance. These ceremonies, documented in historical records dating back over 700 years, reinforce collective responsibility for river health while providing cultural continuity across generations. In addition, forest-ordination rituals that blend religious beliefs with conservation principles have protected significant forest areas in the watershed, with community members attributing spiritual significance to certain tree species and forest areas. Interviews with community elders revealed that these sacred areas often align with ecologically sensitive zones such as headwaters and erosion-prone slopes. Traditional taboos and practices that regulate resource harvesting and waste disposal create informal but effective conservation measures, with cultural sanctions against over-extraction of resources from the river system.

The third dimension of natureculture relationships is social organization for resource management. Communities have established collective governance structures blending traditional authority with adaptive decision-making. Traditional Muang-Fai irrigation systems still operate in several communities, with management committees overseeing water allocation based on established rights and responsibilities. These systems feature sophisticated water-sharing agreements, balancing agricultural needs with ecosystem requirements. Communities hold regular seasonal meetings to adjust water allocation based on environmental conditions, while intergenerational knowledge transfer occurs through both formal apprenticeship and everyday practices, enabling communities to adapt to contemporary challenges.

Environmental Challenges and Community Adaptations

Field surveys and interviews highlighted how communities have adapted to emerging environmental challenges through innovative responses that blend traditional knowledge with contemporary approaches. Development of community-based air-quality monitoring networks

represents a significant adaptation to increasing air pollution concerns. Several communities along the Ping River have established volunteer monitoring groups that combine traditional observation methods with low-cost digital sensors. These networks operate in coordination with official government monitoring systems, but provide more localized and frequent data. Community members also reported using this information to adjust daily activities, particularly for vulnerable populations such as children and the elderly, and to coordinate community responses during severe pollution episodes. The data collected further serves as evidence for advocacy efforts aimed at policy changes addressing pollution sources.

The revival of traditional water management practices to address drought conditions has emerged as another adaptive response. Facing increasingly severe dry seasons, communities have reinstated traditional water conservation practices that had declined during periods of relative water abundance. These include the restoration of small water retention areas that historically dotted the landscape along the Ping River, rehabilitation of secondary canals that increase water distribution efficiency, and revival of community agreements regarding water allocation during periods of scarcity (Ruengpanit, 2003). Field observations documented several communities that had successfully restored traditional infrastructure, with elders providing design guidance based on historical knowledge. These systems have proven particularly valuable during the increasingly unpredictable rainfall patterns experienced in recent years.

Integration of traditional ecological knowledge with modern scientific approaches represents a significant pattern of community adaptation observed across the Ping River Basin (Institute for Local Community Development, 1993). In this regard, local knowledge holders collaborate with researchers and government agencies to develop comprehensive environmental management strategies, including biodiversity monitoring programs combining indigenous taxonomic knowledge with scientific methods, integration of traditional weather forecasting with meteorological data, and adaptation of traditional building designs for climate resilience. Similarly, urban-agriculture initiatives have emerged addressing both environmental degradation and food security, with community gardens along restored river sections incorporating traditional crop varieties and cultivation methods. These projects utilize organic waste composting, water-efficient irrigation techniques, and community seed banks while strengthening local ecological connections.

The research identified critical gaps in current environmental education approaches, particularly the disconnect between classroom learning and local ecological contexts. Analysis of school curricula revealed predominantly human-centric approaches positioning nature as a resource rather than recognizing reciprocal relationships (Misiaszek, 2021). Teacher interviews indicated limited awareness of local ecological knowledge systems, and few opportunities for student engagement with knowledge holders. These findings highlighted the need for educational interventions bridging these gaps and fostering integrated understanding of natureculture relationships in the Ping River Basin, providing the foundation for developing the board game intervention described in Table 1.

Table 1

Summary of Qualitative Findings on Spatial Context, Dynamics, and Relationships in the Ping River Basin

Research focus	Key findings	Evidence	Implications for environmental education
Ecological system and environmental dynamics	• Complex interplay of natural and anthropogenic factors • Diverse micro-ecosystems (riparian forests, wetlands, irrigation systems) • Significant environmental challenges (air quality, water degradation, waste management) • Three main drivers of degradation: urbanization, climate change, resource competition	• Biodiversity surveys identifying 120+ plant species and 85+ animal species • Environmental monitoring data showing PM2.5 levels 4× above standards • Water quality assessments revealing DO levels below 2 mg/L • Documentation of 28% urban expansion along river (2010-2023) • Meteorological data showing 1.2°C temperature increase	• Need for educational approaches that address interconnected environmental challenges • Importance of contextualizing environmental issues within local ecosystems • Value of incorporating current environmental data in educational materials
Natureculture relationships	• Sophisticated traditional ecological knowledge systems • Cultural practices embedding environmental stewardship within spiritual frameworks • Collective governance structures for resource management	• Documentation of seven distinct water states identified by elders • Historical records of river blessing ceremonies dating back 700+ years • Field observations of Muang Fai irrigation systems with collective maintenance • Interviews with community elders showing alignment of sacred areas with ecologically sensitive zones	• Opportunities to integrate traditional knowledge in environmental curriculum • Value of incorporating cultural dimensions of environmental stewardship • Potential for bridging scientific and traditional knowledge systems
Environmental challenges and community adaptations	• Community-based air quality monitoring networks • Revival of traditional water	• Documentation of volunteer monitoring groups with combined traditional/digital approaches	• Models of community adaptation for educational content

Table 1
(Cont.)

Research focus	Key findings	Evidence	Implications for environmental education
	management practices • Integration of traditional and scientific knowledge • Urban agriculture initiatives	• Field observations of restored water retention areas and canal systems • Examples of collaborative biodiversity monitoring programs • Community gardens incorporating traditional crop varieties	• Practical examples of natureculture problem-solving • Accessible examples of local environmental action for students • Illustrations of how traditional knowledge addresses contemporary challenges
Gaps in current environmental education	• Disconnect between classroom learning and local contexts • Limited integration of traditional ecological knowledge • Predominantly human-centric educational approaches	• School curricula analysis showing nature positioned as resource to be managed • Teacher interviews indicating limited awareness of local knowledge systems • Few structured opportunities for student engagement with knowledge holders	• Need for educational interventions bridging these gaps • Opportunity for developing more integrated understanding • Importance of moving beyond human-centric approaches

Development of the Environmental Literacy Board Game

The development of the *Ping River Guardians* board game followed a systematic process, integrating contextual findings with educational game design principles. This section details the game design process, expert quality assessment, and pilot testing insights. Through iterative refinement based on stakeholder feedback, complex ecological and cultural knowledge was transformed into an engaging educational tool promoting environmental literacy through local context.

Game Design Process

Based on the Phase 1 contextual data, a board game was developed to foster environmental literacy through local ecological engagement. The Ping River Guardians is a cooperative, turn-based strategy board game for 3–5 players, each taking the role of a community stakeholder (e.g., a traditional knowledge holder, environmental activist, municipal officer, school-teacher, or youth representative) working collectively to protect and restore the Ping River ecosystem.

The game comprises a central game-board, 60 ecosystem-component cards, 40 scenario cards, 30 action cards, 20 community-resource tokens, a shared environmental health tracker, and individual role cards. Scenario cards present authentic local environmental

challenges drawn from Phase 1 findings — for example, "PM2.5 levels have reached dangerous levels due to agricultural burning upstream. Decide how to respond: a) mobilize a community monitoring team using traditional observation methods, b) coordinate with the municipal office to issue a public health alert, or c) organize a school air-quality education campaign."

Then, players collectively evaluate trade-offs, allocate resources, and apply both scientific and traditional knowledge to advance the health-tracker, winning by completing three restoration missions before the tracker reaches a critical degradation threshold. This structure was designed to directly stimulate environmental knowledge (ecosystem and scenario cards), attitudes (role immersion and collaborative deliberation), and conservation behaviors (action planning mechanics).

As shown in Table 2, the game board visually represents the Ping River ecosystem with key ecological zones (highlands, midlands, urban areas, agricultural zones), incorporating topographical features affecting watershed dynamics. Cultural landmarks (temples, markets, community forests) and environmental challenge hotspots corresponding to actual pollution sources were prominently featured. Resource-flow pathways illustrated water, nutrient, waste, and economic resource movements throughout the system, enabling players to visualize the interconnections between different areas and activities within the complex socio-ecological system.

Table 2

Design Components of the Ping River Guardians Board Game

Game component	Key features	Design principles	Connection to environmental literacy
Game board	• Visual representation of Ping River ecosystem • Key ecological zones (highlands, midlands, urban areas, agricultural zones) • Cultural landmarks and traditional community spaces • Environmental challenge hotspots • Resource flow pathways	• Spatial accuracy • Visual hierarchy • Cultural representation • Ecological relationships	• Knowledge of local geography and ecosystems • Understanding of spatial relationships • Recognition of cultural-ecological connections
Game mechanics	• Collaborative decision-making processes • Resource management systems • Scenario cards with authentic challenges • Action cards requiring analytical thinking	• Cooperation over competition • Strategic resource allocation • Real-world problem scenarios • Multiple solution pathways	• Systems thinking development • Resource management understanding • Problem-solving skills • Analytical thinking

Table 2
(Cont.)

Game component	Key features	Design principles	Connection to environmental literacy
	• Feedback mechanisms demonstrating cause-effect relationships	• Visual feedback systems	• Cause-effect comprehension
Learning elements	• Knowledge and understanding components (ecosystem cards) • Impact analysis elements (outcome trackers) • Problem investigation activities (investigation cards) • Participation in solutions (project planning)	• Balance of factual and conceptual knowledge • Integration of traditional and scientific knowledge • Scaffolded learning progression • Active engagement techniques	• Environmental knowledge acquisition • Impact assessment skills • Investigation and evidence gathering • Action planning and implementation

The game-mechanics were designed to promote environmental literacy through multiple interactive elements, as shown in Table 2. Collaborative decision-making forms the core gameplay experience, with players assuming roles as community members with different expertise working together to address environmental challenges. Resource-management systems require players to allocate limited resources to various initiatives, simulating real environmental trade-offs. Scenario cards present authentic local environmental challenges based on documented cases from the Ping River Basin, while action cards require analytical thinking to explore multiple solution pathways. Visual feedback-mechanisms demonstrate cause-effect relationships in ecosystems, reinforcing systems thinking by showing how actions in one area affect conditions elsewhere.

The game incorporates four environmental literacy dimensions through carefully structured learning elements. Knowledge of local ecosystems is developed through ecosystem-component cards containing both scientific information and traditional knowledge about species, habitats, and ecological processes. Impact analysis is promoted through mechanics that require players to anticipate consequences of decisions, with outcome trackers showing effects on environmental and community well-being. Problem-investigation skills are developed through activities requiring data-gathering and interpretation, while participation in environmental solutions is encouraged through action planning mechanics that require gathering appropriate resources and community support for effective implementation.

Quality Assessment Results

The quality assessment of the board game involved a comprehensive evaluation by 11 experts across three domains: content validity, game-mechanics, and educational appropriateness. As detailed in Table 3, environmental-education experts, game-design specialists, and primary-school teachers rated various aspects of the game highly, while

providing targeted recommendations for refinement. Their collective assessment confirmed the game's effectiveness as both an educational tool and an engaging gameplay-experience.

Table 3

Expert Evaluation of Game Quality (n=11)

Evaluation aspect	Expert group	Mean score (5.00)	Key findings	Suggested improvements
Content validity	Environmental education experts (n=3)	IOC = 0.87	• Strong alignment between game content and environmental literacy objectives • Accurate representation of local environmental challenges • Balanced presentation of traditional and scientific knowledge	• Enhance representation of urban-rural interdependence • Strengthen connections between local and global environmental issues
Game mechanics quality	Game design specialists (n=3)	4.52	• Effective integration of learning objectives into gameplay • Collaborative mechanics (4.78/5.00) • Resource management systems (4.65/5.00) • Scenario and action cards (4.45/5.00) • Feedback mechanisms (4.36/5.00)	• Strengthen visual representation of long-term consequences • Enhance player agency in complex scenarios
Educational appropriateness	Primary school teachers (n=5)	4.38	• Suitable vocabulary level for grades 4-6 • Appropriate game duration (30-45 minutes)	• Include additional differentiation options for mixed-ability classrooms • Develop supplementary

Table 3
(Cont.)

Evaluation aspect	Expert group	Mean score (5.00)	Key findings	Suggested improvements
			• Effective discussion prompts • Support for diverse learning styles	activities for extended learning
Implementation feasibility	Primary school teachers (n=5)	4.45	• Compatibility with existing curriculum • Reasonable preparation time • Comprehensive teacher's guide • Flexibility to adapt to current environmental events	• Provide more structured assessment tools • Create digital support materials

Environmental education experts rated the content validity highly (IOC = 0.87), confirming the game effectively represents key environmental concepts and local ecological knowledge. Their assessment noted strong alignment between game content and environmental-literacy objectives, including ecosystem interconnections, causal relationships, and integration of scientific and traditional knowledge. They highlighted the accurate representation of local environmental challenges, while suggesting enhanced representation of urban-rural interdependence and stronger connections between local and global issues.

Game-design specialists evaluated the mechanics positively (mean score of 4.52/5.00), particularly noting the balance between educational content and engaging gameplay. Collaborative mechanics received the highest ratings (4.78/5.00) for fostering meaningful discussions and joint decision-making, while resource-management systems (4.65/5.00) were judged well-calibrated to create meaningful choices without overwhelming complexity. Scenario cards and action cards (4.45/5.00) were assessed as appropriately challenging, though experts suggested strengthening the visual representation of long-term consequences for greater educational impact.

Primary-school teachers assessed the game as appropriate for the target age group (mean score of 4.38/5.00) and rated its implementation potential highly (4.45/5.00). They highlighted age-appropriate complexity, suitable vocabulary level with visual scaffolding, and appropriate game duration (30 –45 minutes) for classroom implementation. Teachers valued the discussion prompts connecting gameplay to curriculum objectives and the game's support for diverse learning styles. They appreciated the compatibility with existing curriculum, reasonable preparation time, comprehensive teachers' guide, and flexibility to adapt scenarios to current environmental events, suggesting additional differentiation options for mixed-ability classrooms.

Pilot Test Findings

Pilot testing with 30 students revealed that initial gameplay-sessions required 50 – 60 minutes rather than the designed 30 – 45 minutes. This led to streamlined set-up procedures, clearer instructions, and quick-reference cards in the final version, reducing subsequent play times to 35 – 40 minutes, which better aligned with classroom constraints. Table 4 summarizes the key challenges identified during pilot testing and the corresponding game refinements implemented to address each issue.

Table 4

Pilot Test Findings and Game Refinements (n=30 students)

Challenge identified	Evidence	Game refinement	Expected outcome
Time management	Initial gameplay sessions required 50 –60 minutes rather than the designed 30 –45 minutes	• Streamlined setup procedures • Clearer initial instructions • Addition of quick-reference cards	Reduced average play time to 35 –40 minutes, better alignment with classroom constraints
Connecting game to real-world	Students navigated gameplay mechanics but missed connections to actual environmental challenges	• Addition of reflection questions to scenario cards • Structured post-game discussion guide	Improved ability to articulate real-world relevance of in-game decisions
Participation balance	Uneven participation among different students	• Enhanced collaborative mechanics • Role cards with specific responsibilities • Structured turn-taking elements	Ensured balanced participation and interdependence among players
Technical vocabulary	Students struggled with terms like “biodiversity,” “ecosystem services,” and “watershed”	• Simplified language while maintaining scientific accuracy • Visual glossary added to game board • Gradual introduction of technical terms	More accessible game content with scaffolded vocabulary learning
Cultural relevance	Higher engagement with scenarios mentioning familiar landmarks and practices	• Additional cultural elements incorporated • Traditional conservation practices featured • Local ecological knowledge emphasized	Strengthened connection between environmental concepts and students’ cultural identities

As shown in Table 4, students needed additional scaffolding to connect game scenarios with real-world environmental challenges despite successfully navigating gameplay-mechanics. Researchers addressed this by adding reflection questions to scenario cards and developing a structured post-game discussion guide for teachers. These additions significantly improved students' ability to articulate the real-world relevance of their in-game decisions, as demonstrated in follow-up interviews, bridging the gap between abstract gameplay and concrete environmental issues.

The collaborative elements prove particularly engaging, with observational data showing high levels of peer interaction, negotiation, and joint problem-solving. Notably, students typically disengaged in traditional classroom activities showed increased participation during gameplay. Teachers observed that the cooperative structure created a supportive learning environment, encouraging risk-taking and creative thinking. The final version enhanced these collaborative mechanics through role-cards assigning specific responsibilities to each player, ensuring balanced participation and interdependence.

Technical vocabulary and cultural relevance emerged as key areas for refinement. Students struggled with terms like "biodiversity" and "ecosystem-services," prompting revisions with more accessible language while maintaining scientific accuracy. A visual glossary and scaffolded introduction of terminology were added to support comprehension. Additionally, teachers noted students' enthusiastic response to scenarios mentioning familiar landmarks and cultural practices. Consequently, the game was enhanced with traditional conservation practices, seasonal festivals, and local ecological knowledge, strengthening connections between environmental concepts and students' cultural identities.

Effects of the Board Game on Environmental Literacy

The implementation of the board game yielded significant improvements across all dimensions of environmental literacy among participating students. This section examines the game's effects on environmental knowledge and understanding, attitudes toward environmental conservation, and actual conservation behaviors, supported by both quantitative and qualitative data. Table 5 summarizes the pretest and posttest results, demonstrating substantial gains in all three components of environmental literacy.

Table 5

Summary of Pretest and Posttest Results on Environmental Literacy Components

Environmental literacy component	Pretest		Posttest		Improvement (%)	Statistical Test	Significance
	Mean	(SD)	Mean	(SD)			
Knowledge and understanding	11.24	3.42	16.85	2.18	49.9%	$t = 15.28$	$p < .001$
Environmental attitudes	3.28	0.75	4.36	0.52	32.9%	$Z = 7.42$	$p < .001$
Conservation behaviors	1.85	0.68	3.24	0.59	75.1%	$t = 12.64$	$p < .001$

Note. Knowledge was measured on a 20-point scale; Attitudes on a 5-point scale; Behaviors on a 4-point scale.

Environmental Knowledge and Understanding

The paired t test analysis revealed a statistically significant improvement in students' environmental knowledge after using the board game (t = 15.28, p < .001), with mean scores increasing from 11.24 (SD = 3.42) to 16.85 (SD = 2.18), representing a 49.9% improvement. Knowledge gains varied across content areas, with the greatest improvements occurring in concepts directly emphasized through game-mechanics and scenarios. As detailed in Table 6, improvements were most substantial in understanding local ecosystem-components (+62%) and traditional-ecological knowledge systems (+59%), demonstrating the game's effectiveness in developing environmental knowledge.

Table 6

Detailed Knowledge Improvement by Content Area

Knowledge area	Improvement (%)	Key findings
Local ecosystem components and interactions	62%	Enhanced ability to identify interdependencies between species, habitats, and human activities.
Environmental challenges in the Ping River basin	55%	Increased ability to describe local issues and their cause-effect relationships.
Traditional ecological knowledge systems	59%	Greater appreciation for indigenous environmental monitoring techniques and conservation approaches.
Urban environmental systems	41%	Improved understanding of urban infrastructure, consumer behaviors, and governance systems.

Understanding of local ecosystem-components and their interactions improved dramatically (+62%), with students demonstrating enhanced ability to identify interdependencies between species, habitats, and human activities. Posttest responses showed sophisticated comprehension of food webs, nutrient cycles, and energy flows within the Ping River ecosystem, often incorporating specific examples from the game. Recognition of environmental challenges specific to the basin increased substantially (+55%), with students accurately describing local issues such as seasonal air pollution, flooding patterns, and water management. Their explanations frequently referenced cause-effect relationships explored during gameplay, indicating transfer of conceptual understanding to real-world contexts.

Awareness of traditional-ecological knowledge systems showed significant growth (+59%), with students demonstrating newfound appreciation for indigenous environmental monitoring techniques, sustainable resource-management practices, and cultural-conservation approaches. This finding is particularly noteworthy given limited attention to traditional knowledge in conventional curricula, suggesting that the game effectively bridged this gap. Comprehension of urban-environmental systems also improved markedly (+41%), with students displaying enhanced understanding of how urban infrastructure, consumer behaviors, and governance systems affect environmental quality. Posttest responses revealed more nuanced perspectives on urban-environmental relationships, moving beyond simplistic views of cities as purely detrimental.

Qualitative analysis of students' written responses indicated not only increased factual knowledge but also increased conceptual sophistication. Pretest answers typically featured fragmented information and linear cause-effect thinking, while posttest responses demonstrated interconnected thinking, consideration of multiple factors, and recognition of feedback loops within environmental systems. This suggests that the game fostered systems thinking abilities alongside content knowledge, supporting deeper understanding of environmental complexity. These findings align with the pattern shown in Table 6, where areas most directly emphasized in gameplay showed the greatest knowledge gains.

Environmental Attitudes

Analysis of the environmental-attitude scale revealed significant positive changes in students' attitudes toward environmental conservation (Wilcoxon $Z = 7.42$, $p < .001$), with mean scores increasing from 3.28 (SD = 0.75) to 4.36 (SD = 0.52) on the 5-point scale. Factor analysis identified improvements across three main attitudinal components: cognitive (beliefs), affective (emotional connections), and behavioral intention (willingness to act). As detailed in Table 7, the most substantial attitudinal shifts occurred in appreciation for traditional-ecological knowledge (+45%) and motivation to participate in conservation activities (+41%), demonstrating the game's effectiveness in fostering pro-environmental perspectives across diverse student demographics.

Table 7

Changes in Environmental Attitudes by Dimension

Attitudinal dimension	Improvement (%)	Key observations
Personal responsibility for environmental protection	38%	Stronger agreement with statements about individual actions making a difference
Appreciation for traditional ecological knowledge	45%	Increased respect for indigenous environmental practices
Concern for local environmental issues	32%	Stronger emotional connections to nearby ecosystems and local challenges
Motivation to participate in conservation activities	41%	Greater willingness to engage in environmental initiatives

Personal responsibility for environmental protection increased significantly (+38%), with students connecting their daily behaviors to broader environmental impacts through cause-effect relationships explored during gameplay. Post-intervention interviews revealed students recognizing that individual choices contribute to collective outcomes - a concept reinforced through the game's collaborative mechanics, where individual actions influenced shared environmental indicators. This structural emphasis on interconnection and collective impact successfully translated into personal attitude changes, demonstrating how gameplay experiences can reshape environmental perspectives, even among young students without prior environmental interest.

Appreciation for traditional-ecological knowledge showed the most dramatic improvement (+45%), with students expressing increased respect for indigenous environmental practices and local conservation approaches. In post-game discussions, students frequently

referenced traditional practices featured in game scenarios, often expressing surprise at their sophistication and relevance to contemporary challenges. This finding is particularly significant given students' limited prior exposure to traditional knowledge systems, suggesting that the natureculture approach effectively countered perceptions that indigenous knowledge is outdated or less valuable than scientific approaches. Simultaneously, concern for local environmental issues showed substantial growth (+32%), with students expressing stronger emotional connections to nearby ecosystems and specific locations featured in the game that they had previously taken for granted.

Motivation to participate in conservation activities increased significantly (+41%), with students expressing greater willingness to engage in environmental initiatives both at school and in their communities. This increased behavioral intention was reflected in action-oriented statements and enthusiastic descriptions of conservation activities they hoped to join or initiate. Many students specifically mentioned elements from the game's action-cards as activities they wished to implement in real life, indicating direct transfer from game scenarios to behavioral intentions. These findings, as summarized in Table 7, demonstrate how the game's emphasis on achievable conservation actions fosters self-efficacy beliefs supporting pro-environmental behavioral intentions, creating a bridge between attitudinal changes and potential behavior change.

Environmental Conservation Behaviors

Behavior-assessment data showed significant increases in students' environmental conservation behaviors after the intervention, with mean frequency scores increasing from 1.85 (SD = 0.68) to 3.24 (SD = 0.59) on a 4-point scale ($t = 12.64$, $p < .001$). Using triangulated evidence from self-reports, parent-verification, teacher-observation, and documented participation, the assessment revealed substantial behavioral changes across multiple domains. As detailed in Table 8, the most dramatic improvements occurred in waste-reduction practices (+85%) and water-conservation behaviors (+72%), with behavioral changes emerging gradually throughout the 12-week intervention period as students translated game-based learning into real-world actions.

Table 8

Environmental Conservation Behavior Changes

Behavior category	Improvement (%)	Evidence of change
Waste reduction and recycling practices	85%	• School waste audits showed measurable reductions in classroom waste • Student-initiated classroom waste reduction campaigns • Transfer of behaviors to home settings
Water conservation behaviors	72%	• Implementation of water monitoring systems • Quantifiable reductions in classroom water consumption • Adoption of specific conservation practices (e.g., turning off taps, collecting rainwater)

Table 8
(Cont.)

Behavior category	Improvement (%)	Evidence of change
Participation in community environmental activities	63%	• Increased student volunteering for environmental projects • Higher participation in eco-clubs and conservation events • Student-initiated environmental projects in schools
Sharing of environmental knowledge with family	68%	• Parent verification of knowledge sharing at home • Family behavior changes influenced by students • Parents reporting learning new information through their children

Waste-reduction and recycling practices showed the most substantial improvement (+85%), with students demonstrating significantly increased frequencies of waste separation, plastic avoidance, and reuse-behaviors. School waste-audits documented measurable reductions in classroom waste-generation and improved recycling compliance, while teachers reported student-initiated waste-reduction campaigns inspired by game scenarios. Parent interviews confirmed the transfer of these behaviors to home settings, with families reporting student-led initiatives to improve household waste-management. The concrete, actionable nature of these behaviors contributed to their high adoption-rate, representing achievable changes within students' direct control and demonstrating how game mechanics translate into real-world behaviors.

Water-conservation behaviors improved dramatically (+72%), with students taking specific actions in both school and home environments, including turning off taps when not in use, reporting leaks, collecting rainwater, and advocating for water-efficient appliances. Several classrooms implemented student-suggested water-monitoring systems similar to those featured in the game, resulting in quantifiable reductions in water-consumption. Interview data revealed students directly connecting these behaviors to game scenarios involving water scarcity and river health, showing clear transfer from game content to daily practices. These improvements were particularly significant given the regional importance of water management in the Ping River Basin, suggesting context-specific relevance enhanced behavior adoption.

The intervention also catalyzed broader environmental engagement, with substantial increases in community participation (+63%) and knowledge-sharing with family members (+68%), as shown in Table 8. Students demonstrated increased volunteering for environmental projects, participation in eco-clubs, and initiated new environmental projects in their schools. This knowledge-sharing behavior created a multiplier effect, extending the intervention's impact beyond direct participants to influence household practices and parental attitudes. Several parents reported learning new information about local ecosystems and traditional-ecological knowledge through their children, highlighting how the game's emphasis on local environmental contexts made the content particularly relevant and shareable within family conversations.

Qualitative Observations

Behavioral observations during gameplay revealed several important patterns, including progressive improvement in systems thinking abilities as students recognized cause-effect relationships in environmental scenarios, enhanced collaborative problem-solving when addressing complex environmental challenges, increased use of environmental terminology and concepts in discussions, and growing ability to transfer game-based learning to real-life situations

Teachers reported that students began applying their learning outside the classroom by initiating waste-separation projects in their schools, discussing environmental issues with family members, connecting classroom learning with observations in their communities, and showing greater interest in local environmental news and events. The most significant change observed was students' transition from viewing environmental issues as abstract problems to understanding them as concrete challenges connected to their daily lives and local communities.

Discussion

This research explored the development and implementation of a board game for enhancing environmental literacy among primary school students within Chiang Mai's urban context. The findings demonstrate significant improvements in students' environmental knowledge (+49.9%), attitudes (+32.9%), and conservation behaviors (+75.1%), highlighting the effectiveness of integrating local ecological contexts with educational approaches that bridge traditional-knowledge and modern learning methods.

The natureculture approach provided a powerful framework for environmental education, particularly in contexts with rich cultural heritage. As described by the Learning in Places Collaborative (2020), traditional educational environments often perpetuate "nature-culture divides" where humans are positioned "apart from" rather than "a part of" the natural world. The "Ping River Guardians" game challenged this human-centric approach by presenting interconnected relationships where human actions and natural processes mutually influence each other, aligning with nature-culture complementarities that position humans within rather than separate from ecological systems. This perspective shift contributed to students' deeper understanding of environmental systems and their connection to local ecosystems, successfully bridging what Soga & Gaston (2016) describe as the "extinction of experience" — the growing disconnects between children and natural environments in urban settings.

The significant improvements across all dimensions of environmental literacy confirm that board games offer powerful educational potential for complex ecological understanding. The game created a safe experimentation space where students could observe consequences of environmental decisions without real-world impacts, supporting what Mannion et al. (2013) describe as necessary rehearsal spaces for environmental learning. Collaborative-mechanics promoted social learning through peer dialogue, visual representations made abstract ecological relationships tangible, and immediate feedback mechanisms reinforced systems thinking by making cause-effect relationships observable (Shimabukuro et al., 2022; Tsai et al., 2019).

Examining specific mechanisms more closely, the cooperative multi-stakeholder role structure most plausibly drove attitudinal shifts, particularly the 45% increase in appreciation for

traditional-ecological knowledge, as students were required to actively voice and negotiate community knowledge holder perspectives. The scenario- and action-card system, drawn directly from phase 1 ethnographic findings, likely explains knowledge gains in traditional ecological knowledge (+59%) and local-ecosystem components (+62%). The environmental health tracker and resource-management mechanics, which rendered cause-effect relationships immediately visible, most plausibly account for the dramatic behavioral improvements in waste-reduction (+85%) and water-conservation (+72%).

It should be acknowledged, however, that these outcomes reflect the board game functioning as the central pedagogical medium within a structured instructional process—including teacher-facilitated reflection, progressive content sequencing, and curriculum integration — rather than gameplay in isolation. Future research employing experimental designs with comparison groups would help disentangle the game's specific contribution from its broader pedagogical context.

A particularly noteworthy finding was students' ability to transfer learning from the game to real-world contexts. The integration of local environmental challenges, cultural practices, and familiar geographical features created authentic learning experiences that facilitated knowledge application beyond the classroom. This supports place-based education theory (Sobel, 2004; Smith & Sobel, 2010) that learning grounded in local contexts enhances relevance and applicability. The observed increases in community participation (+63%) and family knowledge-sharing (+68%) suggest that the board-game effectively bridged school learning and community engagement, demonstrating how indigenous and local knowledge systems can enhance environmental education (Tsai et al., 2021).

The game successfully addressed multiple dimensions of nature-culture relations as outlined in the Learning in Places framework. By integrating human activity (collaborative decision-making), values and knowledge systems (traditional-ecological knowledge), power and historicity (challenging conventional approaches), development and cognition (systems-thinking), and learning environments (culturally relevant contexts), the game created a comprehensive approach to environmental education. The most dramatic improvements occurred in waste-reduction practices (+85%) and water-conservation behaviors (+72%), demonstrating that connecting abstract environmental concepts to concrete local challenges significantly enhanced both understanding and action.

Despite positive findings, several limitations should be acknowledged. The one-group pretest-posttest design limits causal inferences and does not permit isolation of the board-game's specific contribution from surrounding instructional elements, including teacher facilitation, peer interaction, and structured reflection activities. Future studies should employ quasi-experimental or randomized designs with comparison groups to more rigorously attribute outcomes to the game itself. The 12-week implementation period cannot demonstrate long-term sustainability of learning outcomes, suggesting the need for longitudinal follow-up. Additionally, the research was conducted in urban-Chiang Mai schools, and findings may not generalize to rural contexts or regions with different cultural and ecological characteristics.

In addition, future research directions should include exploring digital adaptations of the board game to reach wider audiences, investigating applications of the natureculture approach to other environmental education contexts, examining game-based learning's influence on family and community environmental behaviors, and developing assessment tools that more comprehensively capture systems-thinking development. This study demonstrates that board

games designed with attention to local natureculture relationships can effectively enhance environmental literacy among primary school students, offering a promising pathway for developing the environmental understanding needed to address complex sustainability challenges while fostering a sense of place and cultural identity.

Conclusions

This research demonstrates that board games designed with local natureculture relationships can significantly enhance environmental literacy among primary-school students, as evidenced by substantial improvements in knowledge, attitudes, and behaviors. By challenging the conventional human-centric approach to environmental education and positioning humans as a part of rather than apart from natural systems (Learning in Places Collaborative, 2020), the game effectively bridged what Soga & Gaston (2016) describe as the extinction of experience in urban settings. The study provides empirical evidence that integrating traditional ecological knowledge with engaging educational approaches creates powerful rehearsal spaces where students develop systems-thinking capabilities while connecting abstract concepts to local contexts.

As environmental education evolves to address growing ecological challenges, this place-based education approach offers a promising pathway for developing environmental literacy by simultaneously addressing multiple dimensions of nature-culture relations: human activity, values and knowledge systems, power dynamics, cognitive development, and culturally responsive learning environments - creating educational experiences that prepare students to participate meaningfully in addressing complex sustainability challenges while strengthening connections to their local ecological and cultural heritage.

Author Contributions

OJ: Conceptualization, writing of the original draft, supervision, project administration, and funding acquisition. PN: Validation, formal analysis, investigation, and resources. All authors: Methodology, writing – review and editing, and approval of the published version of the manuscript.

Ethics Statement

This research was approved by the Chiang Mai University Research Ethics Committee (Certificate of Approval No. 124/67, Project Code CMUREC No. 67/182). Informed consent was obtained from all participants' parents or guardians prior to data collection.

Declaration of the Use of Generative AI

During the preparation of this manuscript, the authors used Claude Pro (Anthropic PBC) to assist with language editing and polishing of the draft. The tool was used solely to improve clarity, grammar, and overall readability. The authors reviewed and revised the output as necessary and take full responsibility for the content of the manuscript.

Funding

This research was partially supported by CMU Proactive Researcher Program No. EX010126 and the Research Center for Multiculturalism and Education Policy, Multidisciplinary Research

Institute, Chiang Mai University and corresponded with SDG 4: Quality Education and SDG 11: Sustainable Cities and communities.

References

Boivin, J. A. (2020). Farm-to-table: How one teacher fostered passionate, project-based, place-based learning. *Journal of Sustainability Education*, *24*(1).

Buosonte, R. (2013). *Qualitative research in education*. Chulalongkorn University Press. (in Thai)

Creswell, J.W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson.

Department of Water Resources. (2009). *Local wisdom of water consumption*. Ministry of Natural Resources and Environment. (in Thai)

Duhn, I., Malone, K., & Tesar, M. (2017). Troubling the intersections of urban/nature/childhood in environmental education. *Environmental Education Research*, *23*(10), 1357–1368. https://doi.org/10.1080/13504622.2017.1390884

Goodlad, K., & Leonard, A. E. (2018). Place-based learning across the disciplines: A living laboratory approach to pedagogy. *A Journal of Scholarly Teaching, 13*, 150-164. https://doi.org/10.46504/14201808go

Greenwood, D. A. (2017). Mushrooms and sweetgrass: A biotic harvest of culture and place-based learning. *The Journal of Environmental Education*, *48*(3), 205–212. https://doi.org/10.1080/00958964.2017.1299675

Haraway, D. (2018). Staying with the trouble for multispecies environmental justice. *Dialogues in Human Geography, 8*(1), 102-105. https://doi.org/10.1177/2043820617739208

Institute for Local Community Development. (1993). Community forest in Thailand: Development. *A tropical rainforest with an overview of community forestry in Thailand*. Institute for Local Community Development. (in Thai)

Ito, H., & Igano, C. (2020). Place-based environmental education to promote eco-initiatives: The case of Yokohama, Japan. *Regional Studies, Regional Science*, *7*(1), 292–308. https://doi.org/10.1080/21681376.2020.1794950

Jatuporn, O. (2025). Pre-service teacher preparation model for cultivating posthumanist global citizenship in the urban context. *Kasetsart Journal of Social Sciences*, *46*(1), 460127. https://doi.org/10.34044/j.kjss.2025.46.1.27

Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory*. Oxford University Press. https://doi.org/10.1093/oso/9780199256044.001.0001

Learning in Places Collaborative. (2020). *Framework: Nature-culture relations*. Learning in Places.

Lynch, J., & Mannion, G. (2021). Place-responsive pedagogies in the anthropocene: Attuning with the more-than-human. *Environmental Education Research*, *27*(6), 864–878. https://doi.org/10.1080/13504622.2020.1867710

Mannion, G., Fenwick, A., & Lynch, J. (2013). Place-responsive pedagogy: Learning from teachers' experiences of excursions in nature. *Environmental Education Research*, *19*(6), 792–809. https://doi.org/10.1080/13504622.2012.749980

Misiaszek, G.W. (2021). *Ecopedagogy: Critical environmental teaching for planetary justice and global sustainable development*. Bloomsbury Academic.

Molina-Motos, D. (2019). Ecophilosophical principles for an ecocentric environmental education. *Education Sciences*, *9*(1), 37. https://doi.org/10.3390/educsci9010037

Patton. M. Q. (2002). *Qualitative research and evaluation methods*. Sage Publications.

Pollution Control Department. (2024). *Thailand state of pollution report 2023*. Ministry of Natural Resources and Environment. (in Thai)

Ponrach, P. (2013). A book review in "Ordained forest, destiny revier: Forest and water cultural management". *Journal of Environmental and Sustainable Management, 9*(1), 107-123.

Ruengpanit, N. (2003). *Natural resources and environment conservation*. Kasetsart University Press. (in Thai)

Smith, G. A., & Sobel, D. (2010). *Place- and community-based education in schools*. Taylor & Francis Group.

Sobel, D. (2004). *Place-based education: Connecting classrooms and communities*. Orion Society.

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human-nature interactions. *Frontiers in Ecology and Environment, 14*(2), 94–101. https://doi.org/10.1002/fee.1225

Shimabukuro, M., Toki, T., Shimabukuro, H., Kubo, Y., Takahashi, S., & Shinjo, R. (2022). Development and application of an environmental education tool (board game) for teaching integrated resource management of the water cycle on coral reef islands. *Sustainability*, *14*(24), 16562. https://doi.org/10.3390/su142416562

Somerville, M. (2013). The nature/cultures of children's place learning maps. *Global Studies of Childhood, 3*(4), 407-417. https://doi.org/10.2304/gsch.2013.3.4.407

Tsing, A. L. (2015). *The mushroom at the end of the world: On the possibility of life in capitalist ruins*. Princeton University Press.

Tsai, J.C., Cheng, P.H., Liu, S.Y., & Chang, C. (2019). Using board games to teach socioscientific issues on biological conservation and economic development in Taiwan. *Journal of Baltic Science Education, 18*(4), 634-645. https://doi.org/10.33225/jbse/19.18.634

Tsai, J.C., Liu, S.Y., Chang, C.Y., & Chen, S.Y. (2021). Using a board game to teach about sustainable development. *Sustainability*, *13*(9), 4942. https://doi.org/10.3390/su13094942