

Enhancing Pre-service Teachers' Learning of Water Quality and Microalgae Through the *Water Ranger* Educational Board Game

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Abstract

Active learning through educational board games can effectively enhance learners' interest and participation. This study aimed to (1) design and develop an educational board game to promote learning about water quality and microalgae classification for pre-service teachers, (2) examine the learning achievement of students who used the board game, and (3) investigate users' satisfaction with the board game *Water Ranger*. The participants were 18 pre-service science teachers majoring in Learning Management. Research instruments included a board game usage questionnaire, an achievement test, and a satisfaction survey. Data were analyzed using mean, standard deviation, and Dependent t-test. The results revealed that the *Water Ranger* board game was appropriate for promoting active learning related to water quality and microalgae classification. Students' post-test scores were significantly higher than pre-test scores at the .05 level. Overall satisfaction with the board game was at the highest level (M = 4.57). The study suggests further improvement of the gameplay to increase diversity and challenge to enhance learner engagement. Future implementation with larger groups is recommended to evaluate the board game's potential in promoting knowledge and fostering environmental awareness.

Keywords: board game, game-based learning, microalgae, pre-service teachers, water quality

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Introduction

Water quality is a critical environmental issue that affects ecosystems, public health, and sustainable development worldwide. Microalgae, as bioindicators of aquatic ecosystems, play a significant role in assessing water quality, yet understanding their classification and ecological functions remains challenging for many learners due to the abstract and complex nature of the content (Bellinger & Sigeo, 2015). In science education, particularly at the pre-service teacher level, developing a deep conceptual understanding of environmental topics such as water quality and microalgae is essential, as future teachers must be equipped not only with content knowledge but also with the ability to convey these concepts effectively to their students (Darling-Hammond, 2006).

Traditional lecture-based instruction, while commonly used in higher education, has been increasingly criticized for its limited capacity to foster meaningful learning, critical thinking, and student engagement (Freeman et al., 2014). In response, active learning approaches have gained considerable attention as effective alternatives that promote learner participation, collaboration, and deeper understanding (Bonwell & Eison, 1991). Active learning encompasses a range of instructional strategies that require students to engage in higher-order thinking processes such as analysis, synthesis, and evaluation, rather than passively receiving information (Prince, 2004).

Among active learning approaches, game-based learning (GBL) has emerged as a particularly promising strategy in educational contexts. Educational games create immersive learning environments in which learners can experiment, make decisions, and receive immediate feedback, thereby supporting both cognitive and affective dimensions of learning (Mayer, 2019). A growing body of research has demonstrated the effectiveness of educational games in improving academic achievement and fostering positive attitudes toward learning across various subjects and age groups (Hattie, 2009; Tokac et al., 2019).

Among the various types of educational games, board games have attracted renewed interest as accessible, low-cost, and socially interactive tools for learning. Unlike digital games, board games facilitate face-to-face interaction, collaboration, and communication among players, making them particularly well-suited for classroom environments (Booth, 2015). Studies have shown that educational board games can effectively promote content knowledge, scientific reasoning, and environmental awareness in both formal and informal educational settings (Nebot et al., 2022; Santos et al., 2023).

Despite the growing evidence supporting the use of board games in science education, their application in pre-service teacher education remains underexplored, particularly in the context of environmental science topics such as water quality and microalgae. Pre-service teachers represent a unique and important target group, as their learning experiences during teacher preparation programs significantly shape their future pedagogical beliefs and classroom practices (Zeichner, 2010). Exposing pre-service teachers to innovative instructional tools not only enhances their subject matter knowledge but also broadens their repertoire of teaching strategies, which can ultimately benefit the students they will teach (Darling-Hammond & Bransford, 2005).

In response to this gap, the present study designed and developed an educational board game, named *Water Ranger*, specifically intended to support pre-service science teachers in learning about water quality parameters and microalgae classification. Grounded in the principles of

active learning and game-based learning, the *Water Ranger* board game aimed to provide an engaging, interactive, and educationally meaningful experience that could complement traditional instruction.

Research Objectives

1. To design and develop the *Water Ranger* educational board game to promote learning about water quality and microalgae classification among pre-service science teachers.
2. To examine the learning achievement of pre-service science teachers before and after using the *Water Ranger* board game.
3. To investigate the satisfaction of pre-service science teachers toward the *Water Ranger* educational board game.

Methodology

Research Paradigm

This study adopted a quantitative research paradigm with elements of educational research and development (R&D). The research design employed was a One-Group Pretest-Posttest Design, which is appropriate for examining changes in learning achievement before and after an instructional intervention within a single group of participants. The study also incorporated a descriptive research component to evaluate users' satisfaction. The conceptual framework was grounded in Active Learning Theory (Bonwell & Eison, 1991) and Game-Based Learning (Plass et al., 2015), which together informed the design, development, and evaluation of the *Water Ranger* educational board game.

Participants and Research Context

The study was conducted in the context of pre-service science teacher education at Srinakharinwirot University, Thailand. The participants were 18 pre-service science teachers enrolled in the Learning Management major, selected through purposive sampling. The course in which the board game was implemented focused on science learning management, where pre-service teachers are expected to develop both subject matter knowledge and pedagogical competencies related to environmental science, including water quality and microalgae classification.

Research Instruments

Three research instruments were used in this study. First, a board game usage questionnaire was employed to evaluate the appropriateness of the *Water Ranger* board game by content and pedagogical experts. Second, an achievement test covering water quality parameters and microalgae classification content was administered as both pre-test and post-test. Third, a five-point Likert scale satisfaction survey was used to assess participants' overall experience with board games across four dimensions: content and accuracy, perceived learning value, game design and components, and gameplay and mechanics. All instruments were validated for content validity prior to use.

Research Procedures

The research was conducted in three phases. In Phase 1 (Design and Development), the *Water Ranger* board game was developed through an iterative prototyping process. Content accuracy, instructional design, and gameplay mechanics were validated by a panel of content and pedagogical experts. In Phase 2 (Implementation), participants completed a pre-test, engaged in a facilitated *Water Ranger* gameplay session, and then completed a post-test. In Phase 3 (Data Analysis), data were analyzed using descriptive statistics (mean and standard deviation) and a Dependent t-test to compare pre-test and post-test scores. Satisfaction data were interpreted according to a five-point Likert scale classification: 4.51–5.00 = highest level, 3.51–4.50 = high level, 2.51–3.50 = moderate level, 1.51–2.50 = low level, and 1.00–1.50 = lowest level.

Results

Appropriateness of the *Water Ranger* Educational Board Game

The expert evaluation indicated that the *Water Ranger* board game was appropriate for promoting active learning related to water quality and microalgae classification. Content accuracy, instructional design, gameplay mechanics, and alignment with learning objectives were all rated positively. The game's design successfully reflected the principles of active learning, as the scientific content was embedded directly into the gameplay mechanics, enabling learners to encounter and apply content knowledge in a contextualized and interactive manner.

Learning Achievement

The learning achievement of the 18 participants was assessed using a pre-test and post-test. The results are presented in Table 1.

Table 1

Comparison of Pre-test and Post-test Scores of Pre-service Science Teachers (n = 18)

	Pre-test		Post-test		t
	M	SD	M	SD	
Pre-service Science Teachers (n = 18)	15.83	3.12	22.67	2.45	8.21*

Note. * $p < .05$

As shown in Table 1, the mean post-test score ($M = 22.67$, $SD = 2.45$) was significantly higher than the mean pre-test score ($M = 15.83$, $SD = 3.12$) at the .05 level of statistical significance ($t = 8.21$, $p < .05$). This finding confirmed Hypothesis 2. Furthermore, the decrease in standard deviation from pre-test ($SD = 3.12$) to post-test ($SD = 2.45$) suggests that the group became more consistent in their knowledge of water quality and microalgae classification following the gameplay session.

Satisfaction With the *Water Ranger* Board Game

Participants' satisfaction with the *Water Ranger* board game was assessed using a five-point Likert scale. The results are summarized in Table 2.

Table 2

Overall Satisfaction of Pre-service Science Teachers Toward the "Water Ranger" Board Game (n = 18)

Aspect	M	SD	Level
1. Content and accuracy	4.62	0.48	Highest
2. Perceived learning value	4.61	0.49	Highest
3. Game design and components	4.55	0.51	Highest
4. Gameplay and mechanics	4.50	0.54	Highest
Overall	4.57	0.50	Highest

As shown in Table 2, the overall satisfaction of participants was at the highest level ($M = 4.57$, $SD = 0.50$), confirming Hypothesis 3. All four aspects—content and accuracy ($M = 4.62$), perceived learning value ($M = 4.61$), game design and components ($M = 4.55$), and gameplay and mechanics ($M = 4.50$)—were rated at the highest level. These results suggest that participants viewed *Water Ranger* not only as a scientifically accurate and well-designed tool but also as a genuinely valuable learning experience.

Discussion

Appropriateness of the Board Game Design

The positive expert evaluation of the *Water Ranger* board game is consistent with the broader literature on educational game design, which emphasizes the importance of aligning game mechanics with clearly defined learning objectives (Plass et al., 2015). Effective educational board games translate complex academic content into accessible and engaging gameplay experiences without sacrificing instructional rigor (Booth, 2015). By embedding water quality parameters and microalgae classification into a structured game format, *Water Ranger* allowed learners to encounter scientific content in a contextualized and meaningful manner, which is considered essential for deep learning (Mayer, 2019). The game's design also reflects the active learning principles articulated by Bonwell and Eison (1991), who argue that effective instruction should engage learners in activities that require analysis and problem-solving rather than passive listening.

Learning Achievement

The significant improvement in post-test scores observed in this study is consistent with a substantial body of research demonstrating the effectiveness of game-based learning in enhancing academic achievement. Tokac et al. (2019), in a meta-analysis, reported that

educational games consistently produced positive effects on student achievement compared to traditional instruction. Hattie (2009) similarly identified interactive and engaging instructional strategies as among the most influential factors in learning outcomes. The improvement in this study can be attributed to three features of the *Water Ranger* board game: immediate feedback that allowed learners to correct misconceptions in real time, collaborative gameplay that encouraged peer discussion and explanation (Prince, 2004), and motivational appeal that increased learners' willingness to engage with challenging content (Plass et al., 2015). These findings extend the evidence base for game-based learning to the domain of pre-service environmental science teacher education.

Satisfaction With the Board Game

The highest level of overall satisfaction ($M = 4.57$) reflects the strong potential of *Water Ranger* as an engaging and effective instructional tool. High learner satisfaction with educational games is generally attributed to intrinsic motivational qualities, including challenge, curiosity, and social interaction (Malone & Lepper, 1987). These affective outcomes are recognized as important complements to cognitive gains, as positive emotional experiences during learning enhance long-term motivation and engagement (Plass et al., 2015). The satisfaction results are also consistent with findings from related studies on environment-themed educational board games (Nebot et al., 2022; Santos et al., 2023). Despite the overall high ratings, participants indicated room for improvement in gameplay diversity and challenge, aligning with recommendations that educational games should provide an appropriate and progressive level of challenge to sustain engagement (Csikszentmihalyi, 1990).

Implications and Limitations

The findings carry important implications for science education and pre-service teacher preparation. Educational board games can serve as effective and engaging supplements to traditional instruction, particularly for conceptually challenging and environmentally significant topics. Exposing pre-service teachers to game-based tools during training may expand their pedagogical repertoire and inspire them to incorporate innovative approaches in their own future classrooms (Darling-Hammond & Bransford, 2005; Zeichner, 2010).

However, limitations must be acknowledged. The small sample size of 18 participants limits generalizability. The One-Group Pretest-Posttest Design does not permit direct comparison with a control group, making it difficult to rule out alternative explanations for the observed gains. Future research should employ larger, more diverse samples, experimental designs with control groups, and longitudinal measures to more rigorously assess the long-term effectiveness of the *Water Ranger* board game.

Conclusion

This study designed, developed, and evaluated the *Water Ranger* educational board game as an active learning tool for pre-service science teachers' understanding of water quality and microalgae classification. Findings across three areas—game appropriateness, learning achievement, and user satisfaction—collectively demonstrate that the *Water Ranger* board game is an effective and engaging instructional resource.

The expert evaluation confirmed the game's appropriateness in terms of content accuracy, instructional design, and alignment with active learning principles. The statistically significant

improvement in post-test scores ($t = 8.21, p < .05$) provides empirical evidence of meaningful learning gains in water quality and microalgae knowledge. The highest-level overall satisfaction rating ($M = 4.57$) affirms that the game was not only effective but also well received as an engaging learning experience.

Future development of the *Water Ranger* board game should incorporate greater diversity and challenge in the gameplay to sustain learner motivation. Implementation with larger groups across varied educational contexts is recommended to evaluate scalability and broader impact. As environmental literacy becomes an increasingly urgent priority in science education, tools such as the *Water Ranger* board game offer valuable contributions to the preparation of knowledgeable, motivated, and pedagogically versatile science teachers.

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