Thermoquest Board Game for Grade 9 Learners: Student Performance and Perceptions of the Board Game

Lusenda Jaudian[1], Elesar Malicoban[2], Edna Nabua[3], Monera Salic-Hairulla[4], Ariel Ellare[5], Noel Lito Sayson[6]

[1,2,3,4,5]Department of Science and Mathematics Education, College of Education

[6]Department of Physics, College of Science and Mathematics

Mindanao State University-Iligan Institute of Technology, Philippines

DOI: https://dx.doi.org/10.47772/IJRISS.2025.90400473

Received: 12 April 2025; Accepted: 17 April 2025; Published: 22 May 2025

ABSTRACT

Game-based learning has emerged as an effective strategy to boost engagement and comprehension in science education. In contrast, traditional Physics instruction often leads to low learner interest, particularly in abstract topics like Thermodynamics. This study aimed to develop and evaluate ThermoQuest, a board game designed to enhance Grade 9 learners' engagement and understanding of heat and work concepts. It employed a Research and Development (R&D) framework with a one-group pre-test and post-test design. A needs assessment using a paper-based 20-item diagnostic test among 125 Grade 10 learners revealed that 90% of items were "Not Mastered," indicating significant learning gaps. ThermoQuest includes a wooden board, trivia and question cards, targeting basic recall to higher-order thinking, tokens and dice, manual, and scoring sheet. The game was evaluated by eight expert evaluators, receiving an overall rating of "Very Good" (M = 4.81/5). Most learners scored between 6–15 points in gameplay, with some achieving higher mastery. After implementation with 111 Grade 9 learners, conceptual gains were measured using a 30-item pre-test and post-test, yielding medium normalized gain scores (g = 0.35–0.46). Learners' perceptions, measured via the Intrinsic Motivation Inventory (4-point Likert scale), showed strong agreement in value/usefulness (3.50) and interest/enjoyment (3.41). In-service teachers (N = 8) also rated the game highly in acceptability, usability, and cognitive impact (M = 3.95–4.00). Findings suggest that ThermoQuest is an engaging and promising supplementary tool for teaching heat and work concepts as evidenced by conceptual gains, high motivation ratings, and positive teacher evaluations.

Keywords: Game-based learning, Learners' Perceptions, Physics Education, Students' Performance, ThermoQuest

INTRODUCTION

Physics is considered one of the most challenging subjects in the curriculum [1]. Its difficulty arises from the necessity to master numerous concepts and skills, many of which are directly tied to mathematics—an area often feared by learners [2], [3]. A significant challenge for teachers is addressing the low interest among high school learners in learning physics and fostering their ability to reason through problem-solving [4], [5], [6].

In the Philippines, low performance in science literacy, particularly in Physics, remains a challenge, with persistent misconceptions about concepts like heat and work [7], [8]. Game-based learning (GBL) has emerged as a promising tool to address these gaps, with board games proven effective in enhancing learner engagement and understanding [9], [10].

In alignment with SDG 4 (Quality Education), this study developed ThermoQuest, a board game designed as a supplementary learning material to improve Grade 9 learners' engagement and understanding of heat and work concepts. It aimed to; develop the ThermoQuest board game focused on the concepts of heat and work; evaluate the board game in terms of its goals and objectives, design, components and organization, playability

and playfulness, and usefulness; identify learners' conceptual gain after gameplay; determine the points learners acquire from playing the board game; and determine the perceptions of learners, based on their experience with the ThermoQuest board game, and in-service teachers regarding the game's acceptability and usability in the classroom. Through game-based learning, the study seeks to enhance learner engagement, improve conceptual understanding, and support innovative approaches to teaching Physics.

METHODOLOGY

This study was conducted in one of the public high schools in Iligan City, Philippines. It utilized the Research and Development (R&D) design to develop the ThermoQuest board game. It employed a quantitative approach with qualitative support. A purposive sampling technique was used to select one hundred eleven (111) Grade 9 learners from three sections, and eight (8) expert evaluators—composed of five (5) board game developers and three (3) in-service science teachers. Additionally, five more in-service science teachers participated in completing the perception questionnaire. Data gathering followed the ADDIE instructional design model, which guided the needs assessment, design, development, implementation, and evaluation of the board game. Instruments used included a 20-item needs assessment test, 30-item pre-test and post-test, perception questionnaires for learners and teachers, and a board game evaluation tool. The needs assessment and the pre- and post-tests were paper-based multiple-choice formats adapted from DepEd's standardized test bank and the Grade 9 Science Module, ensuring alignment with the Most Essential Learning Competencies (MELCs). The pre- and post-tests consisted of 30 items each, with identical questions but randomized answer choices in the post-test to minimize recall bias. Additionally, perception questionnaires for both learners and in-service teachers were administered using a paper-based survey, utilizing a 4-point Likert scale with the options: Strongly Agree, Agree, Disagree, and Strongly Disagree.

The ThermoQuest board game consisted of the following components: a wooden board (34 cm × 33 cm × 1.5 cm), question and trivia cards, player tokens and dice, a trifold game manual, and a structured scoring sheet. The board, inspired by the classic game Snakes and Ladders, featured interactive icons such as volcanic steam and ice slides, which represented advancement and setbacks, respectively, instead of ladders and snakes. The board also included additional icons like boosters, trivia icons, and question icons to further enhance gameplay and learning. These icons were designed to reinforce key concepts of heat transfer and work. The question cards, targeting cognitive skills from basic recall to higher-order thinking, were categorized into multiple-choice, fill-in-the-blanks, modified true or false, problem-solving, and essay, totaling over 40 cards, with an additional 10 cards for trivia statements. Each category had specific point allocations, as reflected in the scoring sheet, which tracked individual player performance during gameplay. Questions ranged in cognitive demand, covering conceptual understanding, situational analysis, and computation, allowing for tiered levels of difficulty.

Quantitative data were analyzed using mean and normalized gain. For the qualitative aspect, thematic analysis was conducted on responses to two open-ended questions included in Part 2 of the perception questionnaire for both learners and teachers. The questions asked, "What are the best features of the board game?" and "Which aspects of the board game can be improved?" Responses were manually coded and grouped into themes using an inductive approach to identify common patterns and insights related to the strengths and areas for improvement of the ThermoQuest board game.

RESULTS AND DISCUSSIONS

To establish the need for the board game, a needs assessment was conducted using a standardized multiple-choice questionnaire extracted from the Department of Education's (DepEd) Division Quarter Exams, focusing specifically on heat and work concepts. This was administered to 125 Grade 10 learners in a selected public high school in Iligan City, Philippines, as they had already covered the topic. As shown in Table 1, results revealed that 18 out of 20 test items were marked under the "Not Mastered" category (below 60%), indicating widespread difficulty in grasping these concepts. The lowest-performing items were related to competencies on heat engines and heat transfer, with only 7% and 8% of learners mastering these respectively. No items were classified as "Mastered" (90%-100%). These results are particularly concerning given that the

participants had already been taught the topic, suggesting not only poor retention but also a lack of deep conceptual understanding. The evident gaps in comprehension, even after instruction, highlight the need for improved and innovative teaching strategies—such as game-based learning interventions—to reinforce learning and make abstract Physics concepts more accessible and engaging.

Table 1. Mastery Level of Grade 10 Learners on the Topic Heat and Work, N=125

Questions	**No. of Learners Answered Correctly**	**Mastery Level**	
		%	**Remarks**
1. What is the relationship between heat and the internal energy of an object?	57	46	Not Mastered
2. Explain why adding heat to a substance increases its internal energy.	55	44	Not Mastered
3. What is the key distinction between a spontaneous process and a non-spontaneous process?	61	49	Not Mastered
4. Why is diffusion considered a spontaneous process?	10	8	Not Mastered
5. Explain why a non-spontaneous process can be reversed with continuous external input, while a spontaneous process cannot be reversed without external intervention.	94	75	Nearly Mastered
6. Imagine you are studying the operation of a heat pump used in an air conditioner. The heat pump transfers heat from the indoor air to the outside environment. Which statement accurately describes the primary purpose of the heat pump?	41	33	Not Mastered
7. You are investigating the components of a refrigerator. One of the components is the compressor. What role does the compressor play in the operation of the refrigerator?	74	59	Not Mastered
8. A student is comparing a traditional electric heater with a heat pump for home heating. Which advantage does the heat pump have over the electric heater?	16	13	Not Mastered
9. Which of the following areas of application commonly utilize heat pumps?	82	66	Least Mastered
10. A heat engine is a device that _____.	43	34	Not Mastered
11. The following are examples of heat engines EXCEPT A. Electric Generator B. Electric motor C. Refrigerator D. Steam engine	9	7	Not Mastered
12. The internal energy of a system is initially 40J. The system does 31J of work. What is the system's final internal energy when a total of 80J of energy is added to the system by heal?	34	27	Not Mastered
13. It refers to how well a heat engine operates	31	25	Not Mastered
14. Why are heat engines not 100% efficient?	52	42	Not Mastered
15. Suppose a steam engine releases 138.50J by heat and receives a 200J of energy, what is the efficiency of the steam engine?	46	37	Not Mastered
16. -18. identify how is heat transferred as shown in the pictures.	36	29	Not Mastered
16.  17.  18. 	28	22	Not Mastered
	26	21	Not Mastered
19. In a four-cycle stroke of gasoline engine, what happens to the gas if it is heated inside the engine's cylinder?	42	34	Not Mastered
20. A car is fueled causing it to move. What energy transformation occurs?	56	45	Not Mastered

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

Recognizing this need, the development of Thermo Quest proceeded through four iterative versions. Version 1 was created and presented to the panel for initial critique. Incorporating the feedback, Version 2 was developed and evaluated by the eight expert evaluators (5 board game developers and 3 in-service science teachers). As summarized in Table 2, the board game received an overall mean rating of 4.81 out of 5, interpreted as "Very Good" across all categories. While evaluators recommended minor refinements—mainly regarding durability and instructional clarity—the game's design, components, and educational purpose were well received.

Table 2. Rating of the ThermoQuest Board Game by Expert Evaluators

Category	Average Mean	Interpretation
Goals and Objectives	4.77	Very Good
Board Design	4.80	Very Good
Card Design	4.69	Very Good
Components and Organization	4.97	Very Good
Playability and Playfulness	4.94	Very Good
Usefulness	4.75	Very Good
Overall Mean	4.81	Very Good

Following further improvements, Version 3 was pilot tested with learners, enabling the identification of additional areas for enhancement. This process led to the final version of the board game, which was implemented in actual classroom settings in one of the public high schools in Iligan City. The final version of the ThermoQuest board game included the following components: a durable wooden board designed like a petite chessboard with outdoor laminated stickers, question and trivia cards, custom-designed tokens and dice, a game manual to guide players, and a scoring sheet to track player progress. Figure 1 and Figure 2 illustrates the visual development of the game from its initial draft to the final polished version.

Figure 1. Initial Version of ThermoQuest Board Game

Figure 2. Final Version of ThermoQuest Board Game

During implementation, learners' in-game performance was tracked to further understand engagement and mastery. Table 4 shows the distribution of scores, with the majority of students across sections scoring between 6–15 points. Notably, Section C had more learners scoring in the higher ranges (21–30 points), suggesting that some learners from this section demonstrated substantial mastery of the heat and work concepts through gameplay. While the questions were the same across all sections, the higher scores in Section C may indicate increased peer collaboration, greater familiarity with the content, or more strategic gameplay, which warrant further exploration.

Table 4. Performance of the Learners in the ThermoQuest Game Try-out, N=111

Section	**Point Interval**					
	0-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**
$A_{N=36}$	4 (11.11%)	8 (22.22%)	14 (38.89%)	5 (13.89%)	5 (13.89%)	0
$B_{N=39}$	4 (10.26%)	12 (30.77%)	13 (33.33%)	8 (20.51%)	2 (5.13%)	0
$C_{N=36}$	5 (13.89%)	11 (30.56%)	12 (33.33%)	2 (5.56%)	3 (8.33%)	3 (8.33%)

To assess conceptual learning, Table 3 presents the normalized gain scores of three participating sections (A, B, and C), which included 111 Grade 9 learners from one of the public high schools in Iligan City, Philippines. All sections of Grade 9 exhibited medium gains, with Section A achieving the highest normalized gain of 0.46, followed by Section C (0.38) and Section B (0.35). These results were derived from a 30-item pretest and posttest, using a multiple-choice format adapted from the Department of Education's (DepEd) Grade 9 Science Module. The highest possible mean score for each section was 30, and the reported means reflect the overall

class averages per section. The same questionnaire was administered across all three sections, covering key concepts of heat and work and aligning with the Most Essential Learning Competencies (MELCs). The normalized gain scores suggest that gameplay contributed positively to students' understanding of these concepts.

Table 3. Summary of Normalized Game Scores in Section A, B and C, N=111

Section	Mean Score		Normalized Gain <g>	Interpretation
	Pretest	Posttest		
$A_{N=36}$	9.81	19.06	0.46	Medium
$B_{N=39}$	9.46	16.54	0.35	Medium
$C_{N=36}$	10.31	17.75	0.38	Medium

Learners' perceptions of ThermoQuest were also evaluated using the perception questionnaire from Intrinsic Motivation Inventory with 4-point Likert Scale. As reflected in Table 5, the game scored highest in Value/Usefulness (3.50) and Interest/Enjoyment (3.41), both interpreted as "Strongly Agree." Learners felt engaged and found the game beneficial for learning Physics. They also agreed that the game fostered a fair sense of competence (2.84) and generally disagreed with statements suggesting pressure or tension (2.07), indicating that gameplay was conducted in a relaxed, enjoyable atmosphere.

Table 5. Perception of the Learners on the ThermoQuest Board Game

Category	Average Mean	Interpretation
Interest/Enjoyment	3.41	Strongly Agree
Perceived Competence	2.84	Agree
Pressure/Tension	2.07	Disagree
Value/Usefulness	3.50	Strongly Agree

To complement the learners' perception of the game, Table 6 summarizes the perceptions scores of five in-service science teachers from one of the public high schools in Iligan City, Philippines using a researcher-made perception questionnaire with 4-point Likert Scale. They strongly agreed with the game's Acceptability (4.00), Usability (3.96), and Cognitive Impact (3.95). In-service science teachers recognized the board game as a well-aligned tool with Grade 9 Physics competencies, noting its potential to promote active learning, critical thinking, and knowledge retention.

Table 6. Perception of In-service Science Teachers on the ThermoQuest Board Game

Category	Mean	Interpretation
Acceptability of the Board Game	4.00	Strongly Agree
Usability of the Board Game	3.96	Strongly Agree
Cognitive Impact of the Board Game	3.95	Strongly Agree

The thematic analysis of the learners' and in-service science teachers' qualitative feedback—based on their responses to the questions "What are the best features of the board game?" and "Which aspects of the board game can be improved?"—revealed several recurring themes that reflect both the strengths of the ThermoQuest board game and areas for improvement. One of the most prominent themes is the enjoyable and engaging nature of the game, as both learners and teachers described it as fun, unique, and exciting. Learners particularly appreciated the social interaction and competitive atmosphere, which made learning enjoyable. Teachers echoed this sentiment, noting that the game encouraged active participation and made the concepts of heat and work more interesting for students. This aligns with another emerging theme: cognitive engagement and conceptual reinforcement. Several respondents shared that the board game helped them recall

and apply physics concepts, improve their study habits, and think critically through questions learned through trivia statements. Teachers also observed that the game effectively stimulated students' minds and fostered deeper understanding.

Another key theme focused on the educational design and game components, including the use of tokens, trivia cards, and visual elements like volcanic steam and ice slides. These features were praised for enhancing gameplay and reinforcing scientific content in a creative manner. However, areas for improvement were also identified. Both groups expressed concerns over game mechanics and physical design. Learners suggested enhancements to the difficulty level of questions, inclusion of hints, and adjustment of game time. Teachers recommended providing board borders to contain dice inside the border. Additionally, a desire for improved visual appeal emerged as a common suggestion, particularly regarding the color of tokens and cards. This feedback highlights the importance of combining aesthetic appeal with educational value to maintain engagement.

In summary, the ThermoQuest board game was perceived positively for its fun, interactive, and educational qualities. To further improve its effectiveness as a supplementary learning tool, both learners and educators recommended refinements in design and gameplay mechanics.

CONCLUSIONS

The development and implementation of the ThermoQuest board game proved effective in enhancing Grade 9 learners' engagement and understanding of heat and work concepts. The ThermoQuest board game was highly rated by expert evaluators across various criteria, including goals and objectives, design, components and organization, playability and playfulness, and usefulness. The overall "Very Good" rating (Table 2) suggests that it is an excellent supplementary material for teaching heat and work. Posttest results (Table 3) indicated moderate learning gains across all sections demonstrating the game's potential to enhance conceptual understanding. Additionally, learners found the game enjoyable, motivating, and helpful for learning, showing high interest, low boredom, moderate confidence, minimal anxiety, and high perceived usefulness. In-service Science teachers also found the game highly acceptable, emphasizing its alignment with Grade 9 learning competencies. They rated its usability and cognitive impact positively, confirming its suitability for instructional use. Thus, the ThermoQuest board game serves as a promising supplementary material that supports interactive and meaningful learning in Physics as evidenced by medium normalized gain scores, high learner motivation ratings, and positive evaluations from in-service teachers.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to the Department of Science and Technology (DOST) for their financial support in this research. Special thanks are also extended to the participating learners, in-service teachers, and the school administration for their cooperation and valuable feedback. Their contributions were crucial to the successful development and evaluation of the ThermoQuest board game.

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