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Development of computational thinking and artificial intelligence skills through a board game for primary students in Border Patrol Police Schools

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Abstract This study aimed to develop computational thinking and artificial intelligence (AI) skills and to enhance the learning achievement of primary school students in border patrol police schools through the implementation of a specially designed educational board game. The research adopted a one-group pretest–posttest preexperimental design to evaluate the effectiveness of the intervention. The participants consisted of 45 primary school students selected through cluster sampling, including 15 students from the Chaloem Rat Bamrung Border Patrol Police School and 30 students from the Ban Huai Pao Border Patrol Police School. The research instruments included a board game quality assessment form, a computational thinking and artificial intelligence skills assessment, an interview form, and an achievement test. The theoretical foundation for board game development was derived from four key domains: learning psychology, computational thinking and AI foundations, media and technology theory, and contextual learning principles relevant to rural educational settings. The board game was designed to encourage problem decomposition, pattern recognition, abstraction, algorithm design, and comprehension of basic AI concepts such as perception, data representation, and machine learning. The findings revealed that students demonstrated notable improvement in both computational thinking and AI-related problem-solving skills after participating in the board game activities. Moreover, statistical analysis indicated a significant increase in students' learning achievement at the 0.05 level, with the mean test score rising from 5.60 in the pretest to 14.13 in the posttest out of a total score of 20. These results suggest that integrating game-based learning strategies can effectively foster computational thinking and AI understanding among young learners in remote educational contexts, thereby promoting 21st-century skills development in primary education.

Keywords: board game, computational thinking, artificial intelligence, border patrol schools

1. Introduction

Computational thinking is a critical skill in K–12 curricula worldwide. Its core principles form the foundation of artificial intelligence (AI) technologies. By promoting computational thinking, learners gain a better understanding of AI concepts and mechanisms. Zerega and Milrad (2023) noted that computational thinking and AI are closely related. Problem-solving processes in computational thinking—such as decomposing problems, using logic, designing algorithms, and abstract thinking—are essential for analyzing and developing complex AI systems.

AI can support the development of computational thinking skills through tools such as interactive learning and intelligent tutoring systems (Tian, 2024). Wing (2006) suggested that computational thinking should be a fundamental skill for everyone, not just computer science students. In terms of instructional design, Su and Zhong (2022) advised educational programs to incorporate technologies such as robotics to build understanding and positive attitudes toward AI. This helps learners develop the mindset and awareness needed to use AI effectively in the digital age. The development of AI-related skills should start in preschool and continue through upper secondary education. This approach lays a strong foundation for future careers in the digital world. Touretzky et al. (2019) created age-appropriate guidelines to promote AI literacy. They outlined key content for students at each stage, including artificial intelligence, machine learning, and robotics, to equip future citizens with sustainable knowledge and skills.

In Thailand, computational thinking is taught to primary students through the Scratch programming platform (Sittisak et al., 2022). Scratch is effective in developing four key components: decomposition, pattern recognition, abstraction, and algorithm design. Digital games on Scratch—focused on sequences, conditionals, loops, and easy gameplay—have also improved computational thinking (Sungkaew et al., 2023). Jantarasena and Asanok (2020) used visual programming tools from

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Code.org and Scratch to create engaging tasks, boosting students' computational thinking. For artificial intelligence, innovations have promoted skills in perception, knowledge representation and reasoning, machine learning, natural interaction, and societal impact. These studies show that digital tools such as computers and smartphones and software such as Scratch are needed to develop computational thinking and AI literacy. However, reliance on such technology can cause educational inequality, especially in remote areas or schools with fewer resources, where students face barriers to effective learning.

Remote schools lack instructional equipment. Border Patrol Police Schools, in particular, still struggle with low information literacy among students (Roobyai et al., 2025). They also have a shortage of teaching materials, insufficient instructional tools, and curricula that do not match local contexts (Choeybal et al., 2019). Sountonchot (2022) reported limited access to modern media, digital technology, and internet connectivity in much of the country. These challenges worsen educational inequality and hinder the growth of students' digital and computational thinking, as well as their AI skills.

One approach to addressing the digital technology access gap in remote schools is through unplugged learning, which does not require the use of computers. A comparative study of computer science education practices in six countries, including the United Kingdom, Finland, Japan, China, South Korea, and Singapore, revealed that primary-level instruction does not necessarily require computers and can instead be delivered through activity sets or board games. This approach aligns with the findings of Apostolellis et al. (2014) and Septiyanti et al. (2020), who reported that learning through games enhances student motivation and improves academic achievement. Additionally, Wei-Chen and Ting-Chia (2020) reported that board games promote greater interaction among learners and foster higher levels of thinking. Similarly, Von et al. (2019) and Thammabut et al. (2022) discovered that using board games can effectively support concepts related to computational thinking, algorithms, and programming while also fostering motivation, positive learning experiences, and peer interaction.

On the basis of background and significance, promoting computational thinking skills and foundational knowledge of artificial intelligence at the primary education level still faces limitations in terms of access to technology. This is particularly true for border patrol police schools, which lack sufficient resources and appropriate learning materials. Therefore, this study aims to develop students' computational thinking and AI skills using board games as an unplugged learning tool that does not rely on digital devices. This approach is designed to align with the context of schools in remote areas and serves as a practical strategy for reducing educational inequality.

2. Research Objectives

The objectives of this research are (1) to develop a board game that promotes computational thinking and artificial intelligence skills among primary school students in Border Patrol Police Schools; (2) to enhance students' computational thinking and artificial intelligence skills through the use of the developed board game; and (3) to improve students' academic achievement through the use of a board game that promotes computational thinking and artificial intelligence.

3. Materials and methods

This study used a preexperimental design with a one-group pretest–posttest format. Loei Rajabhat University exempted the research from human research ethics review under project code HE027/2566.

3.1. Population and Sample

The population consisted of 318 primary school students from eight border patrol police schools in Loei Province. The sample comprised 15 students from Chaloem Rat Bamrung Border Patrol Police School and 30 students from Ban Huai Pao Border Patrol Police School, selected through cluster random sampling.

3.2. Research instruments

3.2.1. Board game quality assessment form

This instrument evaluated the quality of the board game designed to promote computational thinking and artificial intelligence. The assessment covered three dimensions—content, media, and design—comprising a total of 22 items on a 5-point rating scale. The experts validated the assessment and determined that the index of item-objective congruence (IOC) was 1.00.

3.2.2. Computational thinking and artificial intelligence skills test

This instrument assesses students' computational thinking and AI skills on the basis of established conceptual frameworks for both domains. The test used a subjective format and divided the questions into two parts, totaling nine items. The experts reviewed the test results and reported an IOC ranging from 0.67-1.00. The discrimination index ranged from 0.40 to 0.80, and the reliability coefficient of the test was 0.66.

3.2.3. Semistructured interviews on computational thinking and artificial intelligence

This interview instrument was designed to explore students' computational thinking and AI skills. It covered content aligned with the conceptual frameworks of both domains. The semistructured format was validated by experts, who reported an IOC value of 1.00, indicating strong alignment with the research objectives.

3.2.4. Academic achievement test

This multiple-choice test assesses academic achievement, focusing on logical reasoning skills for explaining and designing solutions to real-life problems, as well as basic knowledge of artificial intelligence. The test consisted of 20 items. Expert evaluation revealed that the IOC ranged from 0.67-1.00, the discrimination index ranged from 0.40-0.80, and the reliability coefficient was 0.66.

3.2.5. Student satisfaction questionnaire

This questionnaire evaluated students' satisfaction across three dimensions: content, media, and design. It consists of 22 items on a 5-point rating scale. Expert validation confirmed that the IOC for all the items was 1.00, indicating alignment with the evaluation objectives.

3.3. Data collection and analysis

3.3.1. Quality of the board game promoting computational thinking and artificial intelligence

Data were collected by presenting the instrument to three experts specializing in content, media, and design to evaluate the quality of the board game. The evaluation was conducted via the Board Game Quality Assessment Form, which was designed to promote computational thinking and artificial intelligence. The data collected were analyzed via an interpretive summary and an analytical description. The interpretation of the mean scores was based on the following criteria:

A mean score of 4.50–5.00 indicates excellent quality.
A mean score of 3.50–4.49 indicates good quality.
A mean score of 2.50–3.49 indicates moderate quality.
A mean score of 1.50–2.49 indicates low quality.
A mean score of 1.00–1.49 indicates very low quality.

3.3.2. Students' computational thinking and artificial intelligence

The process began with learning activities designed to connect students' prior knowledge with new knowledge. It also introduced methods for learning through a board game that promotes computational thinking and artificial intelligence. The students were then divided into small groups of 3 to 5 members to engage in the assigned learning activities. During the data collection, the students completed the computational thinking and artificial intelligence skills tests and participated in interviews related to those skills. Each group then engaged with the board game designed to promote the targeted skills and summarized the knowledge gained, as well as the problem-solving approaches developed through the learning process. The teacher subsequently provided a recap of the key content to reinforce understanding.

Qualitative data were analyzed via protocol analysis, followed by interpretation summaries and analytical descriptions. The quantitative data, specifically the means and standard deviations, were analyzed via descriptive statistics. The results were then interpreted and presented in an analytical and explanatory format.

3.3.3. Academic achievement

Data on academic achievement were collected by administering pretests and posttests to the students. The objective was to compare students' knowledge and understanding before and after learning through a board game designed to promote computational thinking and artificial intelligence. The data were analyzed via descriptive statistics, specifically the means and standard deviations. A paired t test was then employed to compare the pretest and posttest scores to determine whether the difference was statistically significant. The results were summarized and interpreted through an analytical description.

3.3.4. Student satisfaction

Data on student satisfaction were collected via a satisfaction questionnaire. The data were analyzed via descriptive statistics, specifically the mean and standard deviation, followed by an interpretive summary and an analytical description. The interpretation of the mean scores was based on the following criteria:

A mean score of 4.50–5.00 indicates the highest level of satisfaction.
A mean score of 3.50–4.49 indicates a high level of satisfaction.
A mean score of 2.50–3.49 indicates a moderate level of satisfaction.

A mean score of 1.50–2.49 indicates a low level of satisfaction.
A mean score of 1.00–1.49 indicates the lowest level of satisfaction.

4. Results

The results of developing computational thinking and artificial intelligence skills through a board game for primary school students in Border Patrol Police Schools are presented below.

4.1. Results of Board Game Development Promotion of Computational Thinking and Artificial Intelligence

The development process of the board game designed to promote computational thinking and artificial intelligence began with the synthesis of a theoretical framework consisting of four core foundations: (1) learning psychology, (2) computational thinking and artificial intelligence, (3) media and technology theories, and (4) the learning context. These components are illustrated in Figure 1.

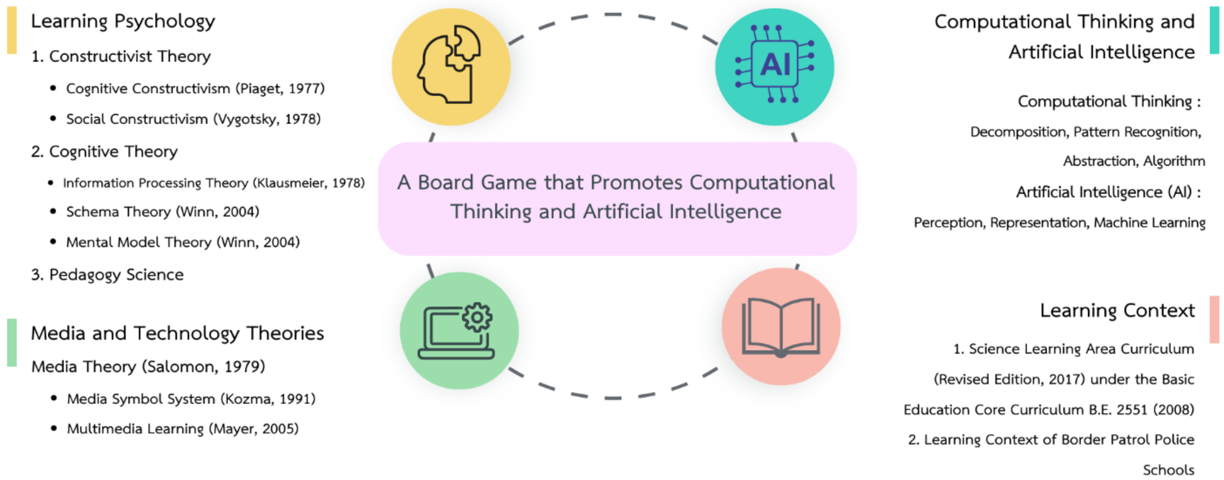

Figure 1 Theoretical framework of the board game promoting computational thinking and artificial intelligence.

The board game was developed to promote computational thinking and artificial intelligence by designing problem-based scenarios that stimulate students' curiosity (Piaget, 1977). These scenarios were embedded in a storyline presented through cartoon characters, where students assumed roles and completed missions to collect space gems. The game consisted of 22 stages, each requiring students to collaborate in problem-solving and coconstruct knowledge (Vygotsky, 1978). Examples of activities included selecting essential items for exploring a forest or finding the shortest route through a given path.

Additionally, the learning content was designed on the basis of information processing theory (Klausmeier, 1978) to help students organize knowledge via schemata or mental models (Winn, 2004). The game also integrates media theory (Salomon, 1979), symbolic systems of media (Kozma, 1991), and multimedia learning theory (Mayer, 2005), which utilize both text and visuals to enhance information processing. The goal was to help learners understand and apply knowledge effectively throughout the learning process.

The evaluation of the board game's ability to promote computational thinking and artificial intelligence revealed that its overall quality was good ($\bar{x}$ = 3.92, S.D. = 0.56). The content dimension was rated good ($\bar{x}$ = 3.93, S.D. = 0.46), the media dimension was also rated good ($\bar{x}$ = 4.33, S.D. = 0.49), and the design dimension was likewise rated good ($\bar{x}$ = 3.75, S.D. = 0.55).

4.2. Results of students' development in computational thinking and artificial intelligence skills

4.2.1. Computational Thinking Skills

Before the intervention, the students lacked systematic computational thinking skills. They were generally unable to break down problems into clear subproblems and often approached problem-solving step by step on the basis of the situation without recognizing recurring patterns or sequences. The students tended to consider all available information without filtering for relevance. Although they attempted to generate solutions, they were unable to formulate the most effective solutions.

With respect to artificial intelligence, students were able to describe human sensory perception, such as using the eyes for vision, but could not fully explain how computers perceive their environment. For example, they were unable to specify the types of sensors required to detect light, sound, or temperature. Their problem-solving methods often rely on trial and error, resulting in inefficient use of time.

After the learning activities, the students demonstrated improved computational thinking and artificial intelligence skills aligned with the defined theoretical framework. The specific details of their development are described below.

4.2.2. Students were able to break down complex problems into subproblems

The students demonstrated the ability to decompose a larger problem into smaller subproblems, reducing complexity and making it more manageable. For example, in a mission to collect gold coins inside an abandoned house, students were required to collect all three coins and then find the exit. They planned their approach by dividing the task into two subproblems: (1) collecting all three gold coins and (2) finding the way out of the house. To address the first subproblem, the students determined which coin to collect first, typically choosing the one closest to the starting point, followed by the second and third closest coins. After collecting the coins, they focused on finding a path to the exit door.

4.2.3. Students were able to identify repeating patterns in movement

Students were able to recognize repeating movement patterns. For example, one student created a walking path from the starting point to the destination as “right, right, down, down, right, right, down, down.” The student then identified the repeating sequence “right, right, down, down,” which occurred twice. This demonstrated their ability to detect and apply recurring patterns, as illustrated in Figure 2.

Figure 2 Repeating path pattern from the starting point to the destination.

4.2.3. Students were able to focus on relevant and important information

The students demonstrated the ability to identify and focus on relevant and essential information. This was evident in a mission where they had to prepare and purchase supplies for a journey. The challenge required students to select appropriate items on the basis of the following condition: “There are wild animals in the forest, the journey includes entering a dark cave to retrieve a thousand-year-old ginseng, and the trip will take three days.” Students successfully selected eight item cards necessary for the journey, such as food cards, weapon cards, and flashlight cards.

4.2.4. Students were able to develop step-by-step problem-solving strategies

The students demonstrated the ability to create structured, step-by-step approaches to problem solving. For example, they were able to select weapon cards to defeat monsters under the following condition: “To defeat a monster with wings, use a bow; if it has no wings, use a sword.” Students successfully formulated commands by using decision-making cards to choose the appropriate weapon.

In addition, students were able to determine the fastest route by comparing the time required to travel along gravel paths versus regular paths. They calculated the total time for each route to decide which route was faster. For example, one student chose a route consisting of nine regular path tiles and three gravel path tiles. The total time was calculated as (9 tiles × 1 minute) + (3 tiles × 4 minutes) = 9 + 12 = 21 minutes. Another route, considered shorter in distance, included two regular path tiles and six gravel path tiles, totaling (2 × 1 minute) + (6 × 4 minutes) = 2 + 24 = 26 minutes. This comparison helps students make logical decisions on the basis of quantitative reasoning.

4.2.5. Artificial Intelligence Skills

The findings revealed that students demonstrated a range of artificial intelligence-related skills.

1) Students were able to install appropriate sensors to enable a robot to locate gems on the basis of randomly drawn task cards. For example, they installed a color sensor to detect green light surrounding a gem and a sound sensor to identify rhythmic sounds.

2) Students were also able to create and decode numerical codes for communication. One group successfully encoded the message, "Have you reached the destination? Did you find the treasure? Come to this planet immediately," into the code "2 4 3."

3) Students demonstrated the ability to classify gems according to characteristics specified on random cards. For example, given the attributes "no facets, unequal width and length, and orange color," they began by filtering for orange gems, then selected those without facets (e.g., round or oval shapes), and finally chose those with unequal width and length, resulting in an orange, oval-shaped gem.

In addition, the students demonstrated the ability to learn without direct instruction. They independently grouped gems on the basis of self-determined criteria such as shape or color. Some groups even classify gems according to the color of their edges. These findings indicate that students' computational thinking and artificial intelligence skills improved after they participated in board game-based learning activities designed to promote these competencies.

4.3. Results of the development of students' academic achievements

To evaluate the effectiveness of the board game-based learning activities, students' academic achievement was measured through pre- and posttests. The results indicated improvements in posttest scores for both schools, as shown in Table 1.

Table 1 Comparison of pretest and posttest academic achievement using the board game.

Schools	N	Paired Differences					t	p value
		$\bar{x}$	S.D.	SE Mean	95% CI for mean difference			
					Lower	Upper		
1. Chaloem Rat Bamrung								
Pretest	15	5.60	1.88	0.48	-9.59	-7.46	-17.19	0.00
Posttest	15	14.13	1.68	0.43				
2. Ban Huai Pao								
Pretest	30	7.33	2.23	0.40	-9.20	-6.79	-13.58	0.00
Posttest	30	15.33	1.82	0.33				

The students from the Chaloem Rat Bamrung Border Patrol Police School had an average pretest score of 5.60 (S.D. = 1.88) and a posttest score of 14.13 (S.D. = 1.68) out of a total of 20 points. A comparison of the pretest and posttest scores revealed that the posttest scores were significantly higher at the 0.05 level.

Similarly, students from the Ban Huai Pao Border Patrol Police School had an average pretest score of 7.33 (S.D. = 2.23) and a posttest score of 15.33 (S.D. = 1.82) out of 20 points. The scores were analyzed via a paired t test, which revealed a statistically significant improvement in posttest scores at the 0.05 level.

5. Discussion

5.1. Discussion on the Development of a Board Game Promoting Computational Thinking and Artificial Intelligence

The development of the board game, which was designed to promote computational thinking and artificial intelligence, was grounded in constructivist learning theory. This theoretical foundation guided the design of learning activities within the game, emphasizing student participation in constructing knowledge through the resolution of problem-based scenarios. This approach supports the development of various aspects of computational thinking and artificial intelligence, such as decomposing complex problems into smaller parts, recognizing patterns, abstract thinking, algorithm design, environmental perception, data representation, and machine learning.

The development approach aligns with the study by Thammabut et al. (2022), which utilized constructivist theory in conjunction with media theory to design a board game that encourages computational thinking. Their approach emphasized creating problem situations that stimulate cognitive conflict, leading students to seek knowledge and restructure their understanding.

Additionally, the findings are consistent with the works of Nachai and Vongthatam (2021) and Vongtathum et al. (2021), who developed board games to enhance step-by-step problem-solving skills via constructivist principles. The key components of their games included (1) problem scenarios, (2) learning resources or guidance for applying knowledge, (3) group play to foster participation, and (4) helping centers that support student learning.

This analysis shows that the game design approach in this research aligns well with previous theoretical frameworks and studies, particularly in emphasizing experiential learning. The overarching goal was to holistically promote students' computational thinking and artificial intelligence skills.

5.2. Discussion on the development of students' computational thinking and artificial intelligence skills

Prior to the intervention, students lacked computational thinking and artificial intelligence skills, as outlined by the theoretical framework established in the study. After participating in the learning activities, they demonstrated improvements in several areas. In terms of computational thinking, students developed skills such as decomposing complex problems into smaller parts, recognizing patterns, abstract thinking, and algorithm design. With respect to artificial intelligence, they gained the ability to perceive environmental inputs (both human- and machine-based), represent and reason with data, and understand the concept of machine learning.

These findings suggest that, after engaging with the board game designed to promote computational thinking and artificial intelligence, students were able to solve tasks in accordance with the conceptual framework developed by the researchers. This outcome aligns with the findings of Rodríguez et al. (2020), Özkök (2021), Sittisak et al. (2022), and Pangkariya and Poonpaiboonpipat (2020), who conducted studies on learning innovations that foster computational thinking through four core components: problem decomposition, pattern recognition, abstraction, and algorithm design.

Furthermore, the results are consistent with research by Eguchi et al. (2021) and Touretzky et al. (2019), who applied the K–12 AI education guidelines from ai4k12.org. These guidelines identify five core concepts in artificial intelligence education: (1) perception, (2) representation and reasoning, (3) learning, (4) natural interaction, and (5) societal impact. These concepts serve as the foundation for enhancing students' understanding of artificial intelligence.

5.3. Discussion on the development of students' academic achievements

The findings revealed that after participating in board game-based learning activities designed to promote computational thinking and artificial intelligence, students' posttest scores were significantly higher than their pretest scores at the 0.05 level of statistical significance. Specifically, the average pretest scores were 5.60 and 7.33 (S.D. = 1.88 and 2.33) out of 20 points, whereas the posttest scores increased to 14.13 and 15.33 (S.D. = 1.68 and 1.82), respectively. These results indicate that board game-based learning had a statistically significant effect on improving students' academic achievement.

One possible reason for this improvement is the learning process embedded in the board game, which emphasizes active participation, problem-based scenarios, and peer learning through group collaboration. These elements support deep content understanding and align with constructivist learning theory, which encourages learners to build knowledge through direct experience.

This finding is consistent with previous studies by Yaiwong and Onthanee (2023), Thammabut et al. (2022), and Sumlee and Phumpuang (2021), which showed that using board games as instructional tools can effectively enhance academic performance, particularly by increasing student engagement, content comprehension, and participation in learning. Overall, the results underscore the potential of board games as powerful educational tools for fostering quality learning in basic education contexts.

6. Conclusions

This research highlighted the development of a board game designed to enhance computational thinking and artificial intelligence skills on the basis of four theoretical foundations: learning psychology, computational thinking and AI, media and technology theory, and the learning context. The game featured problem-based scenarios that stimulated curiosity. It assigned students roles to complete missions across 22 stages, encouraging collaborative learning through computational and AI-related thinking. The quality assessment results indicated that the board game was of good quality, confirming its potential as an effective educational tool for developing these skills. Before using the board game, students lacked core computational thinking abilities, such as breaking down problems, recognizing recurring patterns, and selecting relevant information, and often relied on inefficient trial-and-error methods. The understanding of machine perception in AI contexts was also limited. After the intervention, the students demonstrated improved skills in problem analysis, logical reasoning, and effective solution design. They also gained a clearer understanding of machine perception, indicating the broader applicability of their AI knowledge. Statistical analysis of learning achievements from two Border Patrol police schools revealed that students' posttest scores were significantly higher than their pretest scores at the 0.05 level, demonstrating that board game-based learning effectively enhanced both their computational thinking skills and understanding of artificial intelligence.

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7. Declarations

7.1. Ethical considerations

This study was approved by the Loei Rajabhat University Ethics Committee for Human Research (Ref. No. HE 027/2566). All procedures followed the Declaration of Helsinki, and informed consent was obtained from the participants and their guardians.

7.2. Use of artificial intelligence (AI)

The authors declare that the generative artificial intelligence (AI) tool ChatGPT was used exclusively for language editing and grammatical improvement. The use of AI did not influence the scientific content, study design, data analysis, data interpretation, results, or conclusions of the manuscript. Full responsibility for the content remains with the authors.

7.3. Conflict of Interest

The authors declare that they have no conflicts of interest.

7.4. Funding

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