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Enhancing analytical thinking in grade 8 science education: Integrating 5E inquiry-based and 5W1H techniques

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ABSTRACT

This research investigates how combining the 5E Inquiry-Based Approach with the 5W1H technique can improve analytical thinking skills among eighth-grade students. This action research included two educational sessions following a detailed teaching plan, targeting 36 eighth-grade students who scored below 70% in their placement tests. The teaching plan was adjusted and improved throughout the research. The analysis of the collected data showed that students' analytical thinking skills were significantly enhanced. Furthermore, students reported finding this combined method helpful, especially in building on what they already knew and learning to ask meaningful questions. The study underlines the success of this approach and its contribution to developing new teaching strategies in science education. It suggests areas for future research and practical application in teaching, highlighting the need for student-focused teaching methods and support to fully realize students' abilities. This study points out the value of merging the 5E and 5W1H methods to develop comprehensive skills and improve the learning experience in modern classrooms.

1. Introduction

In recent years, there has been growing recognition of the effectiveness of inquiry-based learning in educational settings, particularly in teaching scientific subjects. One popular and widely adopted approach is the 5E inquiry-based learning model. The 5E model comprises five stages: Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 2009; Duran and Duran, 2004). This instructional method encourages active participation, critical thinking, and problem-solving skills among students, making it an ideal choice for fostering learning in various subjects (Duran and Dökme, 2016). Moreover, the versatility of the 5E model allows for seamless integration with other teaching techniques, enhancing its adaptability and applicability.

Complementing the 5E model is the 5W1H technique, a mnemonic that stands for "What, Who, Where, When, Why, and How." This method is commonly used to gather information and elicit answers to essential questions related to a specific topic (Al-Abbasi and Al-Shablawi, 2022). By employing the 5W1H technique, students are encouraged to analyze, investigate, and comprehend the subject matter more thoroughly, which in turn strengthens their grasp of the material. The incorporation of the 5W1H technique within the 5E inquiry-based learning approach provides an additional layer of depth to the learning process.

Analytical thinking is a crucial cognitive skill for students, especially those in the second grade of junior high school, as it significantly impacts their future education, career paths, and life decisions (Hollett and Cassalia, 2022). Analytical thinking enables students to assess information critically, make informed judgments, and develop problem-solving skills (Perdana et al., 2019; Robbins, 2011). Nurturing analytical thinking in students equips them with the tools necessary to tackle complex challenges and adapt to a constantly evolving world. However, fostering analytical thinking skills can be a challenging task for both students and teachers (Krumhansl, 2016; Sartika, 2018). Some students may struggle to transition from passive learning to an active analytical approach. Similarly, educators may face difficulties in designing activities that effectively engage students and promote analytical thinking. This study seeks to address these obstacles by integrating the 5E inquiry-based learning model

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with the 5W1H technique to apply in a science course while simultaneously fostering their analytical reasoning skills. By integrating these two pedagogical approaches, students could engage in an interactive and investigative learning experience that would develop a higher level of analytical thinking. Consequently, the current study employed the integration of these instructional methods to improve analytical thinking skills among 8th-grade students. The foundation for a more engaging, effective, and enriching educational experience for students is the expected outcome of the project.

2. Literature review

2.1. Analytical thinking in education

In the realm of education, analytical thinking refers to a cognitive ability that has become increasingly indispensable in the 21st century for students to navigate both their professional careers and daily lives (Beňo et al., 2020; Yurt, 2022). This skill involves the capacity to engage in thorough investigation and effectively handle uncertain or ambiguous situations. In educational settings, analytical thinking plays a vital role in addressing unclear contexts, where learners are required to identify or construct problems to be solved (Miterianifa et al., 2021). By honing analytical thinking in problem-solving, young individuals are better prepared to tackle the multifaceted challenges of life and the dynamic workplace in the modern era (Limbach and Waugh, 2010; Yen and Halili, 2015). A key aspect of analytical thinking lies in its ability to deconstruct complex problems, enabling students to comprehend the individual components at play. Moreover, it encompasses the capacity to explain the mechanisms of a system, deduce reasons behind specific phenomena or problem-solving approaches, conduct thoughtful comparisons and contrasts between various elements, and critically evaluate and assess entities or situations (Yani and Mulyadi, 2022). By fostering analytical thinking in education, students are equipped with a powerful cognitive tool that empowers them to approach challenges and uncertainties with greater confidence and proficiency.

2.2. Processes of analytical thinking

As analytical thinking is closely tied to problem-solving, the processes of analytical thinking can be regarded as essential procedures that guide individuals through a systematic approach to addressing problems and arriving at effective solutions (Üredi and Kösece, 2020). These processes play a crucial role in enabling individuals to approach challenges with a well-structured and rational mindset, leading to more successful outcomes. The first step in the process is to define the problem clearly. This involves precisely understanding the nature of the problem, its underlying causes, and the desired outcomes. By defining the problem accurately, individuals can set a clear direction for their analytical thinking and problem-solving efforts. Subsequently, individuals engage in gathering and interpreting relevant information related to the problem. This process entails conducting research, seeking various perspectives, and analyzing data to gain comprehensive insights into the issue. Effective information gathering ensures a well-informed analysis, which is essential for generating effective solutions.

Once the information is gathered, the next stage involves developing possible solutions. Analytical thinkers explore various approaches and strategies to address the problem creatively. They consider multiple perspectives, brainstorm ideas, and evaluate potential solutions based on their feasibility and potential impact. The next step involves testing the possible options to evaluate the effectiveness of the proposed solutions. This testing phase allows individuals to simulate scenarios, conduct experiments, or engage in trial and error to assess the viability and practicality of each solution. Testing helps refine and fine-tune potential approaches, eliminating less promising options. Finally, after careful consideration and evaluation, the individual selects and implements the most suitable solution to resolve the problem effectively. Analytical thinkers weigh the pros and cons of each solution and make informed decisions based on evidence and reasoning.

2.3. The 5E inquiry-based learning model

The 5E inquiry-based learning model is a powerful teaching method utilized in science education to enhance student learning and engagement. Following the five stages of Engage, Explore, Explain, Elaborate, and Evaluate, this approach enables students to study cooperatively and actively draw from their own background knowledge (Science problems were solved through the 5E questioning method). This model, conceptualized by Bybee (2009) and Duran and Duran (2004), focuses on fostering a deep understanding of class concepts by connecting them to students' real-life experiences.

The 5E inquiry-based learning model comprises five stages: Engage, Explore, Explain, Elaborate, and Evaluate. In the Engage stage, teachers spark students' interest by posing questions and quizzes related to the subject, encouraging them to draw upon prior knowledge. During Explore, students actively investigate the topic through examples and experiments, connecting new information with existing knowledge. The Explain stage involves teachers providing comprehensive explanations and demonstrations, solidifying understanding. Elaboration prompts students to apply their learning through projects, reinforcing comprehension. Lastly, the Evaluate stage assesses students' knowledge and skills, identifying areas for further attention. This

model fosters engagement and enhances comprehension by actively involving students in the learning process.

The 5E approach is designed to encourage students' logical thinking and critical reasoning skills, making it a constructivist and student-centered learning model (The model relies on students' logic and critical thinking). It emphasizes active participation and boosts pedagogical actions to enhance students' engagement and comprehension. This inquiry-based learning method effectively assesses students' knowledge, raises pertinent questions, and helps them develop their potential in relation to the lesson's content (This method assesses students' knowledge, raises concerns, and helps them develop lesson-related potential).

2.4. 5W1H techniques

The 5W1H technique, an effective information-gathering and problem-solving technique, involves asking a set of fundamental questions to comprehensively understand a situation or issue (Al-Abbasi and Al-Shablawi, 2022). The acronym stands for "What, Where, When, Who, Why, and How." By systematically addressing these open-ended questions, individuals gain a holistic view of the subject matter, leaving no aspect unexplored. This method is widely used across various disciplines, including journalism, research, project management, and education, to ensure a thorough analysis and promote critical thinking. As an essential tool for problem-solving and decision-making, the 5W1H method empowers individuals to delve into complex scenarios, assess multiple perspectives, and make informed and well-rounded judgments.

The 5W1H method can significantly contribute to the development of analytical thinking as it involves a systematic process of questioning to understand and analyze problems comprehensively by encouraging learners to engage in the systematic exploration of "What, Where, When, Who, Why, and How" aspects of a given situation, the method fosters critical thinking and problem-solving skills. The process of questioning prompts learners to approach problems in a structured and methodical manner, examining all relevant dimensions and perspectives. As analytical thinking is intricately connected to problem-solving, the practice of using the 5W1H method helps learners develop their ability to dissect complex issues, identify relevant information, and make informed decisions. This analytical approach enables individuals to tackle challenges effectively, draw connections between various elements, and arrive at well-grounded conclusions. By consistently applying the 5W1H method, learners hone their analytical thinking abilities, ultimately becoming more adept problem-solvers in various aspects of their lives.

The 5W1H method can be seamlessly integrated into the Explore stage of the 5E inquiry-based learning model. During this stage, students actively investigate the topic through hands-on experiments and exploration (Bybee, 2009; Duran and Duran, 2004). By incorporating the 5W1H method, educators can empower students to ask the right questions as they conduct their experiments. Encouraging students to ponder "What, Where, When, Who, Why, and How" while exploring the empirical data related to the class concepts allows them to gain deeper insights and make meaningful connections. Therefore, they become more engaged in the learning process. They begin to analyze the data collected from various perspectives, drawing connections between different aspects of the experiment. This analytical approach not only strengthens their problem-solving abilities but also helps them develop a broader understanding of the underlying concepts. This would allow students to become more active participants in their learning. By encouraging them to seek answers through their inquiries, educators foster a sense of curiosity and ownership over the learning process. Students become more motivated to explore and discover, driving them to delve deeper into the subject matter.

2.5. Previous studies

Scholars have employed the 5E model as a technique in inquiry-based learning in the science classroom, and the results of the previous studies can be synthesized to show its effects on both learners' knowledge and thinking skills. In science education, the integration of the 5E model has shown positive impacts on students' learning achievement. Studies conducted by Bantaokul and Polyiem (2022), Choowong and Worapun (2021), Eroğlu and Bektaş (2022), Koyunlu Ünlü and Dökme (2022), Thangjai and Worapun (2022), and Yonyubon et al. (2022) consistently highlighted how using the 5E model improves students' science learning outcomes. These studies cover various science topics, such as light and image, heat and temperature, STEM education, magnetism, and inquiry learning characteristics. The 5E model's structured approach, involving engagement, exploration, explanation, elaboration, and evaluation, allows students to delve deeper into scientific concepts, connecting them to real-life experiences and promoting a deeper understanding of the subject matter. The gamification, prediction observation, explanation strategy, and game-based learning elements further enhance students' engagement and interest in science learning.

Furthermore, the 5E model proves beneficial in developing thinking skills, as indicated by the research. The model's systematic and inquiry-based approach fosters analytical thinking, critical reasoning, and problem-solving abilities. Koyunlu Ünlü and Dökme (2022) highlighted the 5E model's role in promoting skill-based STEM instruction within the context of 21st-century skills. By encouraging students to ask questions, explore, and make connections, the 5E model nurtures curiosity and empowers students to think critically and creatively. Eroğlu and Bektaş (2022) also

emphasized the effect of the 5E model on scientific creativity, further supporting its positive impact on developing students' thinking abilities.

One notable gap in the existing studies on the 5E inquiry-based learning model is the encouragement for researchers to explore the integration of other instructional methods and their effects on different topics within science education. Previous research has shown promising outcomes when combining the 5E model with various strategies, leading to improved learning achievements and enhanced cognitive skills in students. Building on this, the current study seeks to address this gap by integrating the 5W1H technique with the 5E model to teach a Work and Energy course. The purpose of this study is to examine the effect of a 5E Inquiry-Based Approach with the 5W1H technique in developing grade 8 students' learning achievement of Work and Energy, as well as its impact on their analytical thinking skills. By investigating the combined approach's effectiveness, this research aims to contribute valuable insights into optimizing science education practices and enhancing students' cognitive abilities.

3. Methodology

3.1. Research design

The study was conducted following an action research approach (Kemmis et al., 2014), structured into two learning circles: planning, acting, observing, and reflecting. In detail, a learning management plan was implemented, with the first learning circle covering 50% of the class contents through planning, acting, observing, and reflecting. The plan's effectiveness was assessed by evaluating the number of participants who met the predetermined criteria. Based on the observations and outcomes from the initial circle, the plan was refined and improved. The enhanced plan was then employed to teach the remaining 50% of the class content, ensuring a continuous cycle of action, evaluation, and refinement for optimal instructional effectiveness.

3.2. Participants

The study included 36 students from a public school in Thailand who were purposefully selected based on their placement test scores not meeting the minimum criteria of 70%. It's important to note that the participants' anonymity and confidentiality were strictly maintained throughout the research process. Moreover, ethical considerations were adhered to, ensuring that the participants were not subjected to any harm or discomfort during the research. The selected samples should accurately mirror the diversity of the Thai educational context, focusing on areas that fall within the middle range in terms of national education assessment and socio-economic factors. This additional information has been included in the revised version. The researchers also made efforts to obtain necessary permissions from the school administration and relevant authorities to conduct the study within an ethical framework.

3.3. Instruments

3.3.1. Learning management plan

The learning management plan was designed considering the integration of the 5E inquiry-based learning and 5W1H technique. There are 9 lesson plans covering the topics of 1) Work, 2) Energy, 3) Simple Machines (Inclined Plane and Wedge), 4) Simple Machines 2 (Pulley), 5) Simple Machines 3 (Wheel and Axle), 6) Simple Machines 4 (Screw and Lever), 7) Gravitational Potential Energy, 8) Kinetic Energy, and 9) Energy Conservation Principles. In detail, the 5W1H technique was integrated into the explore stage of the 5E model. The details can be seen in Table 1.

The learning management plan was subjected to rigorous evaluation by a panel of five experts, consisting of two experienced scholars specializing in learning management design and three professional teachers with expertise in the subject matter. The evaluation process aimed to assess the plan's effectiveness, appropriateness, and alignment with the learning objectives. The consensus among the experts was highly positive ($\bar{x}$=4.40, SD=0.54), indicating that the plan was deemed suitable and effective at a high level. The experts' valuable insights and feedback affirmed that the learning management plan successfully incorporated the 5E inquiry-based learning model and the 5W1H method, providing students with a comprehensive and engaging learning experience.

3.3.2. Analytical thinking test

The analytical test is a written test consisting of a single item that assesses three aspects: Prioritize analysis, relationship analysis, and principles analysis. The test is evaluated using a holistic rubric with a maximum score of 5 points. The test item is designed to measure students' ability to prioritize information, identify relationships between different elements, and apply relevant principles to analyze the given scenario. The difficulty level of the test is measured at 0.65. The discrimination index is 0.84, and the reliability of the test is measured by the coefficient of 0.91. This indicates high internal consistency and the test's ability to produce consistent and accurate results across different administrations.

3.3.3. Interview

A semi-structured interview was developed to provide qualitative data on students' perceptions of the learning management plan. The interview comprises four key sections related to learning management, learning material, instruction, and

students' self-belief in analytical thinking and comprehension of Work and Energy concepts. Each section contains two open-ended questions that aim to gather in-depth insights from participants regarding their teaching practices and beliefs. The interview guide allows for flexibility and encourages participants to share specific examples and experiences related to their instructional strategies and approaches. The Index of Item Objective Congruence of each item was 0.5-1.0.

Table 1: Integrated 5E inquiry-based learning and 5W1H technique learning activities for each topic

Stage of 5E inquiry-based learning	Activities
Engage	Start the lesson by showing a short video clip of various activities involving work, such as lifting objects, pushing a cart, or using simple machines. Ask thought-provoking questions like "What do you notice in these activities?" or "How do you think work is related to these actions?"
Explore	Integrate the 5W1H method into the Explore stage of the 5E inquiry-based learning model. Investigating Simple Machines Objective: To explore the concept of work and energy using simple machines What - Students identify the different types of simple machines and their functions (e.g., inclined plane, wedge, pulley, wheel and axle, screw, lever) Where - Students examine various real-life scenarios where simple machines are used to make work easier (e.g., ramps, door hinges, pulley systems, bicycles) When - Students explore how the use of simple machines has evolved over time and in different cultures (e.g., ancient Egypt's use of ramps in construction) Who - Students research and present information on inventors and scientists who contributed to the development of simple machines Why - Students investigate the advantages of using simple machines to reduce the amount of force needed to perform tasks How - Students conduct hands-on experiments to measure the force and distance involved in using simple machines, calculating the work done in different scenarios
Explain	After the exploration phase, facilitate a class discussion where students share their findings and observations. Provide explanations on the concepts of work, energy, and the different types of energy (kinetic and potential) using real-world examples. Use diagrams and visuals to help illustrate the key concepts
Elaborate	Assign group projects where students have to design and build their own simple machines to perform specific tasks that involve work and energy. For instance, they can create a pulley system to lift a heavy object or design a lever to launch a projectile. This activity encourages creative thinking and problem-solving while reinforcing the concepts learned
Evaluate	Conduct assessments to evaluate students' understanding of work and energy concepts

3.4. Data collection and data analysis

The data collection for this study followed an action research approach (Kemmis and McTaggart, 1988), as explained above. In the first learning circle, the topics of Work, Energy, Simple Machines (Inclined Plane and Wedge), and Simple Machines 2 (Pulley) in the learning management plan were implemented. During this phase, the participants' analytical thinking skills and perceptions were assessed to determine the effectiveness of the initial plan. The evaluation focused on the number of participants who met the predetermined criteria for understanding and comprehension of the subject matter. After the initial learning circle, observations and outcomes were carefully analyzed to identify areas for improvement.

Based on these findings, the learning management plan was refined and enhanced to address any identified shortcomings and enhance instructional effectiveness. The improved plan was then employed in the second learning circle, which covered the topics of 5 Simple Machines 3 (Wheel and Axle), Simple Machines 4 (Screw and Lever), Gravitational Potential Energy, Kinetic Energy, and Energy Conservation Principles. Participants' analytical thinking skills and perceptions were assessed again to examine the effectiveness of the plan.

Descriptive analysis was applied to the quantitative data, allowing for an examination of frequencies, percentages, and means of participants' scores in both tests. On the other hand, thematic analysis was employed to explore the qualitative data derived from the semi-structured interviews.

4. Results and discussion

Thirty-six individuals who did not meet the predetermined criteria of scoring above 70% on the placement test were selected to participate in the project with a specific focus on improving their analytical thinking skills. The performances of these selected participants in both learning circles 1 and 2 are presented in Table 2. The results of the study indicate that 25 participants (69.44%) passed the criteria in the analytical thinking assessment. On the other hand, 11 participants (30.56%) had not met the criteria yet. Overall, the participants' average score in the analytical thinking assessment was calculated as 11.11 (SD=2.26).

Table 2: Participants' analytical thinking skills in learning circles 1 and 2

n	Participants passing the criteria		Participants not passing the criteria		Analytical thinking skills	
	n	%	n	%	$\bar{x}$	SD
			Learning circle 1			
36	25	69.44	11	30.56	11.11	2.26
			Learning circle 2			
	29	80.55	7	19.45	11.67	1.69

Based on the qualitative analysis of the interviews, it can be concluded that the participants expressed overall satisfaction with their learning experience during the study. They highlighted that the 5E Inquiry-Based Approach, which integrates the 5W1H technique, allowed them to grasp the concepts of work and energy in a hierarchical and organized manner. Among the five stages, the exploring stage emerged as the most enjoyable and engaging activity for the participants, as it provided them with opportunities to actively investigate and discover the empirical data related to the subject matter.

Interestingly, some participants mentioned that they gained insights into the topics even before the teachers clarified them during the explaining stage. The teaching approach on how to ask questions in the searching stage was particularly beneficial, as it enabled them to synthesize relevant data and deepen their understanding of the concepts. However, a few participants reflected on the challenge of lacking previous knowledge about certain concepts, making it difficult for them to comprehend the new knowledge effectively. This finding suggests that bridging the gap in prior knowledge could be essential in facilitating a smoother learning experience for all participants. Overall, the qualitative data shed light on the positive aspects of the integrated instructional approach while also highlighting the need for additional support to address individual learning gaps.

Therefore, based on the feedback and reflections from the participants, we made adjustments to the learning activities by incorporating more recap sessions in the engage stage. The additional recap sessions were designed to address the participants' need to reinforce prior knowledge and bridge any gaps in understanding before delving into new concepts. We aimed to create a stronger foundation for learning and enhance the participants' overall comprehension of the Work and Energy topics. The adjustments were implemented to ensure a more inclusive and effective learning experience, allowing all participants to actively engage and benefit from the integrated 5E Inquiry-Based Approach with the 5W1H technique.

The results of the study indicate that in learning circle 2, 29 participants (80.55%) passed the criteria in the analytical thinking assessment, demonstrating a significant improvement in their analytical thinking skills. However, 7 participants (19.45%) had not yet met the criteria, suggesting that further support may be beneficial to enhance their analytical thinking abilities. Overall, the participants' average score in the analytical thinking assessment was calculated as 11.67, with a standard deviation of 1.69. These findings suggest that the integrated 5E Inquiry-Based Approach with the 5W1H technique in learning circle 2 had a positive impact on the participants' analytical thinking development, yet some individuals may still require additional guidance and reinforcement.

In the follow-up interviews with students who did not pass the criteria in the analytical thinking assessment, several challenges emerged. Many of these students revealed that their limited participation in the exploring sessions hindered their understanding of the empirical data and concepts. Consequently, they struggled to comprehend the information presented by teachers during the explain stage. Moreover, the complexity of analytical skills posed a significant obstacle for them, as they lacked a clear understanding of the underlying concepts. As a result, they felt uncertain about how to approach the analytical thinking assessment and experienced difficulties in completing it effectively. These insights provide valuable feedback for improving instructional strategies and providing targeted support to help students develop their analytical thinking skills and enhance their learning experiences in the future.

The results of the study indicate that the integrated approach of 5E and 5W1H is highly effective in science education. These findings align with previous research conducted by Bantaokul and Polyiem (2022), Choowong and Worapun (2021), Eroğlu and Bektaş (2022), Koyunlu Ünlü and Dökme (2022), Thangjai and Worapun (2022), and Yonyubon et al. (2022). One reason for the effectiveness of this approach in developing analytical thinking skills is its focus on providing opportunities for students to construct knowledge from their previous knowledge. The 5E Inquiry-Based Approach encourages students to draw upon their prior experiences and knowledge, enabling them to make meaningful connections and deepen their understanding of the subject matter. By building upon their existing knowledge, students can engage in higher-order thinking and analytical processes, leading to improved problem-solving abilities (Üredi and Kösece, 2020).

Additionally, the 5W1H technique, which emphasizes asking questions, plays a crucial role in enhancing analytical thinking. By encouraging students to inquire and explore various aspects of a problem, the 5W1H technique fosters critical thinking and analytical skills. Students learn how to approach a problem from multiple angles, consider different perspectives, and analyze information systematically. This questioning process leads to a deeper comprehension of complex topics and helps students develop their analytical abilities.

Furthermore, the integrated approach of 5E and 5W1H not only enhances analytical thinking but also brings about satisfying learning experiences. These positive outcomes align with the findings of Choowong and Worapun (2021), Thangjai and Worapun (2022), and Yonyubon et al. (2022). The interactive and hands-on nature of 5E engages students in active learning, making the classroom environment more enjoyable and dynamic. Moreover, the structured questioning process in 5W1H encourages student participation and empowers learners to take ownership of their learning journey. This level of engagement and

autonomy contributes to a positive and learner-centric classroom atmosphere, making the learning process more enjoyable and effective for students.

5. Conclusion

In conclusion, this study aimed to examine the effect of integrating the 5E Inquiry-Based Approach with the 5W1H technique in developing grade 8 students' analytical thinking skills. Following an action research approach, two learning circles were designed and implemented to assess the effectiveness of the instructional method. The quantitative data analysis revealed that the integrated approach led to improvements in students' analytical thinking skills. Moreover, the qualitative data provided valuable insights into students' perceptions and experiences, supporting the positive impact of the integrated approach on their learning journey.

The primary contribution of this study lies in demonstrating that the 5E Inquiry-Based Approach can indeed be effectively integrated with the 5W1H technique to enhance students' analytical thinking skills. By incorporating opportunities for students to construct knowledge from their prior experiences and encouraging them to ask critical questions, the integrated approach fosters deeper understanding, problem-solving abilities, and higher-order thinking. These findings contribute to the existing body of research, affirming the potential of such integration to facilitate holistic thinking skill development among students in science education.

In light of the study's outcomes, several suggestions are offered for both academic and pedagogical contexts. Academically, educators and researchers are encouraged to further explore and integrate innovative instructional methods to enhance students' learning experiences and cognitive development. The integration of inquiry-based learning approaches with techniques like 5W1H presents promising avenues for future research, exploring their applicability across various disciplines and grade levels. Pedagogically, this study underscores the importance of creating engaging and interactive learning environments that foster active participation and analytical thinking. By incorporating inquiry-based activities and structured questioning techniques, teachers can empower students to take ownership of their learning and cultivate a deeper understanding of complex concepts. Furthermore, addressing individual learning gaps through targeted support and differentiated instruction can help ensure that all students have equal opportunities to excel in their academic pursuits.

However, it is important to acknowledge several limitations in this study. Firstly, the sample size was relatively small, consisting of only 36 grade 8 students. This limited sample size may affect the generalizability of the findings to a broader population. Additionally, the absence of a comparative group makes it challenging to definitively attribute the improvements in analytical thinking skills solely to the integrated approach, as other factors may have influenced the results. Furthermore, the study primarily relied on self-report measures for data collection, which could introduce response bias or subjectivity into the results. Finally, while qualitative data was mentioned, it was not collected systematically, which may have provided a more comprehensive understanding of students' experiences and perceptions. These limitations should be considered when interpreting the study's outcomes and in future research endeavors.

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Compliance with ethical standards

Ethical consideration

This study was conducted in accordance with the ethical standards of Bankaewittayayon School, Mahasarakham University, and the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study. Each participant was informed about the purpose of the research, the procedures used, potential risks, and their rights to confidentiality and withdrawal from the study without any penalty. Written consent was obtained prior to participation.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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