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Integrating 5E inquiry-based learning and STEM education to enhance grade 5 students' science process skills and achievement in friction

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ABSTRACT

This research examines the impact of a teaching plan that combines the 5E inquiry-based learning model with STEM (Science, Technology, Engineering, and Mathematics) principles on the science process skills and learning achievement of grade 5 students in the topic of friction in a Thai educational context. The study used classroom action research to evaluate whether students achieved specific skill and knowledge objectives. A purposive sampling method was used to select 45 grade 5 students from a public school. The tools used included the integrated 5E-STEM teaching plan, a science process skills test, and a friction learning achievement test. Data were analyzed using percentages, mean scores, standard deviation, and a paired samples t-test. The results showed significant improvements in students' science process skills and learning achievement, highlighting the benefits of adopting innovative teaching approaches like 5E inquiry-based learning and STEM education. However, the small sample size and absence of qualitative data suggest the need for further research to refine and expand these practices.

1. Introduction

Science education is crucial at all levels of academic study, especially in elementary school, where its fundamental principles are first exposed (Alberts, 2022; Holbrook, 2010). During this phase, students not only gain crucial knowledge but also develop the abilities needed to understand how their environment operates (Moran, 2022). For example, comprehension of friction provides individuals with knowledge about other occurrences, such as the motion of objects and the functioning of machinery. This might lead them to understand how vehicles operate on roads, the efficiency of various tools and equipment, and even the mechanisms behind everyday activities like walking or writing. By exploring real-world examples where friction is involved, such as the grip of tires on a road surface or the interaction between surfaces in contact, students gain practical insights that enhance their understanding of scientific concepts and their applications in daily life. Therefore, scientific education is essential in equipping young learners with the necessary knowledge and skills for their future academic and professional activities (Ha et al., 2013).

To succeed in the field of science, students must develop science process skills that allow them to think with a scientific mind (Choirunnisa et al., 2018; Yumusak, 2016). According to Kurniawati (2021), these abilities can be divided into two main categories: fundamental skills and integrated skills. Basic skills refer to essential procedures such as observing, measuring, classifying, and asking questions. On the other hand, integrated skills entail more intricate activities such as forming hypotheses, planning experiments, identifying variables, and analyzing results. Furthermore, science process skills encompass tasks such as generating and analyzing data or visuals, utilizing principles, formulating deductions, and proficiently conveying discoveries through both spoken and nonverbal methods. Acquiring these skills is of utmost importance in elementary science education, as they form the fundamental basis for scientific investigation and exploration. Through the acquisition of these procedures, students cultivate the capacity to actively and thoughtfully interact with scientific principles, carry out experiments, scrutinize data, and effectively convey their

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discoveries (Sari et al., 2023). This skill set is important for achieving triumph in both scholarly and practical environments.

However, developing science process skills is not a simple task, particularly in the early stages of education (Anderman et al., 2012; Jessani, 2015; McCOMAS et al., 1998). Students may encounter challenges in effectively observing, measuring, classifying, or formulating questions to acquire scientific data. Consequently, the development of science process skills becomes a significant challenge in science education globally. In the specific context of Thailand, where this study is situated, science education, along with the broader education system, has faced criticism for being perceived as monotonous and uninspiring. This sentiment is echoed in various indicators such as national test scores, international test scores (OECD, 2022), and research studies (Damrongpanit et al., 2024; Faikhamta et al., 2018), which highlight deficiencies in students' scientific literacy and proficiency. This suggests a pressing need to reevaluate and enhance science education practices to foster a more engaging and effective learning environment conducive to the development of science process skills.

Considering the nature of science process skills, it becomes evident that they require a systematic approach to questioning—inquiring in a scientific manner. Hence, the adoption of inquiry-based learning emerges as a pivotal strategy in teaching these skills. Inquiry-based learning involves a student-centered approach where learners actively explore concepts, ask questions, investigate phenomena, and construct explanations through hands-on experimentation and critical thinking (Coffman, 2017; Meier and Sisk-Hilton, 2013). Through active participation in genuine scientific investigation, students cultivate a more profound comprehension of scientific principles and methodologies while refining their scientific procedural abilities.

Moreover, the nature of young learners in elementary school necessitates active participation, collaboration, and creativity in the learning process. This is where the integration of STEM (Science, Technology, Engineering, and Mathematics) education proves to be beneficial. STEM education promotes interdisciplinary learning experiences that encourage students to apply knowledge and skills from multiple disciplines to solve real-world problems (Khalil et al., 2023; Sen et al., 2018; Ültay et al., 2020). STEM education promotes creativity, critical thinking, and innovation in pupils by combining science, technology, engineering, and mathematics principles. This prepares them for the requirements of the modern workforce in the 21st century.

Therefore, this study aims to combine inquiry-based learning within the framework of the 5Es model and STEM education to foster the development of Grade 5 students' science process skills and enhance their learning achievement in the context of friction. The findings of this study hold the potential to make significant contributions to the field of science education by elucidating effective strategies for integrating inquiry-based learning within the 5Es model and STEM education in science classrooms at the elementary school level. Furthermore, it offers insights into the pivotal role of science process skills in facilitating students' understanding of complex scientific concepts, such as friction within the realm of science education.

2. Literature review

2.1. Scientific process skills

Scientific process skills encompass a range of abilities that enable individuals to engage in scientific inquiry and investigation effectively (Kurniawati, 2021; Öztürk et al., 2010; Yumusak, 2016). These skills progress from fundamental observations, comparisons, and classifications to more intricate data gathering, interpretation, and hypothesis formulation. Yumusak (2016) delineated various dimensions of scientific process skills, categorizing them into cognitive and affective aspects. In the cognitive aspect, learners develop skills such as observation, forecasting, explanation, hypothesis formulation, inquiry, planning, and communication. These cognitive abilities facilitate the systematic exploration and understanding of natural phenomena, guiding individuals through the scientific inquiry process (Samputri, 2020). On the other hand, from an affective perspective, scientific process skills encompass adaptive qualities such as flexibility, curiosity, critical thinking, risk-taking, and skepticism (Choi et al., 2016). These effective skills foster an open-minded approach to scientific inquiry, encouraging individuals to question, challenge, and adapt their understanding in response to new evidence and perspectives.

Furthermore, scientific process skills are often categorized into core and consolidated skill sets. Core skills include fundamental processes like observation, comparison, classification, inference, forecasting, and communication (Kurniawati, 2021; Samputri, 2020). These foundational skills form the basis for more advanced scientific inquiry. In contrast, consolidated skills involve higher-order processes such as determining and controlling variables, hypothesizing and testing, data gathering and interpretation, operational definition, experimentation, and modeling. These could enable students to design and conduct experiments, analyze data, and draw meaningful conclusions. It's important to note that integrated science process skills often require the utilization of multiple basic-level skills concurrently.

This multidimensionality underscores the necessity of presenting scientific process skills to students in a developmentally appropriate manner, guiding them to apply these skills across various contexts in their lives.

2.2. 5E inquiry-based learning

5E inquiry-based learning is a pedagogical approach that emphasizes active student engagement, exploration, and inquiry throughout the learning process (Bybee, 2009; Duran and Duran, 2004; Ong et al., 2021). Unlike traditional education, which often relies on the passive reception of information from the teacher, inquiry-based learning centers around posing questions, presenting problems or exploring real-world scenarios to stimulate curiosity and critical thinking.

The 5E Inquiry-Based Learning model encompasses five stages, each facilitating a distinct aspect of the learning process. The Engage stage initiates inquiry by captivating students' interest and activating prior knowledge through engaging activities or questions. Subsequently, the Explore stage encourages hands-on investigation, fostering observation, data collection, and hypothesis formulation. In the Explain stage, students articulate their findings, promoting effective communication and collaborative sense-making. The Elaborate stage extends understanding through further exploration or application, deepening conceptual grasp. Finally, the evaluation stage assesses learning through various methods, providing feedback and fostering reflection on students' progress. Together, these stages foster a dynamic learning environment conducive to active engagement, critical thinking, and meaningful learning outcomes.

The efficacy of the 5E technique in science education has been consistently supported by previous research findings (Bantaokul and Polyiem, 2022; Eroğlu and Bektaş, 2022; Manzo et al., 2016; Sen and Oskay, 2016; Udonsathian and Worapun, 2024; Yakob et al., 2020; Yonyubon et al., 2022). These studies collectively suggest that the 5E technique is instrumental in enhancing students' understanding of scientific concepts, fostering critical thinking skills essential for science learning, and cultivating positive attitudes toward science education.

2.3. STEM education: An interdisciplinary approach

STEM education, an acronym for Science, Technology, Engineering, and Mathematics, represents a holistic approach to learning that integrates knowledge and skills from these four core disciplines (El Islami et al., 2024; Khalil et al., 2023; Sen et al., 2018; Ültay et al., 2020). STEM education focuses on preparing individuals for the modern world's demands by emphasizing practical application, problem-solving, and critical thinking instead of rote memorization and passive learning. It aims to create connections between disciplines and use their strengths to tackle real-world challenges and opportunities.

The essence of STEM education lies in its active learning approach, which encourages hands-on exploration and experimentation (Khalil et al., 2023). For instance, project-based and problem-based learning activities encourage students to engage in authentic experiences that mirror the challenges and intricacies of the real world. This approach not only deepens conceptual understanding but also cultivates essential skills such as creativity, collaboration, and communication. STEM education recognizes the dynamic nature of today's digital landscape and the pivotal role of technology and innovation in driving progress (Sen et al., 2018). As such, it equips learners with the tools and competencies needed to thrive in an ever-evolving society. By emphasizing practical application and experiential learning, STEM education empowers individuals to become adaptable problem solvers and lifelong learners (Ültay et al., 2020).

Moreover, STEM education underscores the importance of interdisciplinary integration, bridging the gap between academic knowledge and real-world application. By establishing connections between STEM disciplines and everyday life, learners gain a deeper appreciation for the relevance and impact of their studies (Khalil et al., 2023; Ültay et al., 2020). In essence, STEM education represents a paradigm shift in education, one that prioritizes active engagement, critical thinking, and practical skills development. By embracing an interdisciplinary approach, STEM education equips learners with the knowledge, skills, and mindset needed to navigate the complexities of the modern world and contribute meaningfully to society's advancement.

The incorporation of the 5E inquiry-based learning paradigm into STEM education offers a promising method for instructing the notion of friction in science education. Through the utilization of the Engage phase of the 5E model, teachers can effectively engage students by incorporating practical exercises or real-life situations that emphasize the importance of friction in daily experiences. This initial interaction establishes the foundation for further investigation, during which students actively explore the factors that impact friction and its consequences. The explore stage offers students the chance to perform experiments, collect data, and develop hypotheses, which promotes the development of critical thinking and problem-solving abilities. During this stage, students express their observations and discoveries, enhancing their comprehension of friction and its fundamental principles. The elaborate stage provides opportunities for expanding learning by doing further experiments or applying knowledge in real-world scenarios, enabling students to utilize their understanding in new and unique circumstances. The evaluation stage offers a formative assessment of students' learning, allowing educators to measure mastery and pinpoint areas for further improvement. By combining the 5E model with STEM education, teachers may develop a comprehensive and engaging learning experience that not only improves students' comprehension of friction but also nurtures crucial STEM abilities and encourages a lifelong interest in scientific investigation.

Furthermore, while previous studies have explored the efficacy of the 5E model, there remains a notable call for further investigation into its application across various scientific concepts. Much of the existing research has predominantly focused on the acquisition of knowledge, overlooking its impact on the development of essential skills such as science process skills. Additionally, there exists a gap in the literature concerning the elementary school level, as many studies tend to concentrate on high school students. However, considering the critical juncture of late elementary school, where students are poised to refine their critical thinking abilities in preparation for subsequent educational endeavors, the integration of the 5E model and STEM education presents an intriguing avenue for exploration. Consequently, this study endeavors to bridge these gaps by implementing a combined approach of the 5E model and STEM education within a grade 5 science classroom, with a specific focus on understanding the concept of friction and nurturing science process skills. The purposes of the current study were to examine the effects of the integrated 5E inquiry-based and STEM education learning management on grade 5 students' science process skills and to examine the effects of integrated 5E inquiry-based and STEM education learning management on grade 5 students' learning achievement of friction.

3. Methodology

3.1. Research design

The study adopted a classroom action research methodology (Stringer, 1996) to cultivate the participants' achievement of predefined skill and knowledge objectives. It was organized into two distinct learning cycles facilitated by a learning management system. In the initial phase, the first learning cycle involved the implementation of half of the topics outlined in the learning management plan, incorporating the stages of planning, action, observation, and reflection. The outcomes of this reflection process informed the refinement of activities for the second learning cycle, which covered the remaining topics within the learning management plan.

3.2. Participants

The study comprised 45 grade 5 students from a public school situated within the Thai educational context. Participants were selected using purposive sampling to ensure a representative sample within the context of Roi Et, a province located in northeastern Thailand. Positioned within the middle tier of socioeconomic status and academic performance, Roi Et province offered a suitable demographic representation of elementary school learners within the region. Ethical considerations pertaining to human research were meticulously observed throughout the data collection process, ensuring the participants' rights and well-being were upheld.

3.3. Instruments

3.3.1. The integrated 5E and STEM education learning management plan

The integration of the principles of 5E inquiry-based learning and STEM education culminated in the development of a comprehensive learning management plan. Central to this plan were activities meticulously designed to immerse students in scenarios relevant to friction, thereby facilitating their exploration of scientific concepts. Employing a structured approach encompassing the stages of engaging, exploring, explaining, elaborating, and evaluating lets students be actively involved in their learning journey. Through this process, STEM education principles were intricately woven into each stage, emphasizing hands-on experimentation, problem-solving, and interdisciplinary connections. The learning management plan comprises four sub-lesson plans covering the following topics: 1) The Concept of Friction, 2) Factors Influencing Friction, 3) Increasing and Decreasing Friction, and 4) Benefits of Friction. The plan requires a total of 8 class hours to be completed. The plan underwent evaluation by a total of three scholars and professional teachers, who together determined that it was at an appropriate level, with an average score of 4.61. Prior to implementation in the class, the document underwent revision based on feedback received from expert evaluation.

3.3.2. Science process skill evaluation

The evaluation of science process skills was conducted through a multiple-choice test consisting of 20 items. These items assessed various aspects of science process skills, including observational skills, measurement skills, classification skills, inquiry skills, relationships between space and space and space and time, computational skills, skills in action planning and meaningful communication, skills in analyzing comments from data, prediction skills, skills in hypothesizing, skills in defining operational definitions, skills in determining and controlling variables, experimental skills, and skills in interpreting data and drawing conclusions. The items demonstrated an index of consistency (IOC) ranging from 0.67 to 1.0.

3.3.3. Friction learning achievement test

The Friction learning achievement test was constructed as a multiple-choice assessment comprising 30 items. These items were strategically crafted to evaluate the learning outcomes of the class, aligning with Bloom's taxonomy to gauge students' abilities in memorization, understanding, application, analysis, evaluation, and creation. The items exhibited an index of consistency (IOC) spanning from 0.67 to 1.0.

3.4. Data collection and data analysis

The study employed a classroom action research approach, utilizing two learning circles. Initially, pre-tests were administered to assess both science process skills and learning achievement related to friction. Subsequently, instruction on the topics of "The Concept of Friction" and "Factors Influencing Friction" was carried out using a learning management plan crafted based on the integrated principles of 5E inquiry-based learning and STEM education. The learning circle process encompassed planning, action, observation, and reflection. Following reflection on the outcomes of the first circle, the learning management plan was revised and implemented in the second circle, with instruction on the topics "Increasing and Decreasing Friction" and "Benefits of Friction." Finally, post-tests were conducted to evaluate both science process skills and learning achievement pertaining to friction. The data were analyzed using percentages, mean score, standard deviation, and a paired samples t-test.

4. Results

4.1. The effects of the learning management plan on students' science process skills

Table 1 shows the participants' science process skills before and after the treatment. The results indicate that prior to the treatment, only three students (6.67%) attained a passing score of 50% on the science process skill evaluation, with an average score of 11 (SD = 1.0). However, after the treatment, all 45 students successfully exceeded the 50% threshold, achieving an average score of 13.44 (SD = 1.32). These findings suggest that the learning management plan significantly enhances students' science process skills.

Table 1: The participants' science process skills before and after the treatment

Pre-test							Post-test						
n	Passing students			Non-passing students			n	Passing students			Non-passing students		
	n	x̄ (SD)	%	n	x̄ (SD)	%		n	x̄	%	n	x̄	%
45	3	11 (1.0)	6.67	42	7.71 (1.21)	92.33	45	45	13.44 (1.32)	100	0	0	0

SD: Standard deviation

During the reflection stage of the first learning circle, it became apparent that some students were encountering challenges with fundamental science skills such as observation, data recording, and interpreting results. This difficulty likely stemmed from their limited exposure to scientific experimentation. To address these issues and enhance student learning, adjustments were made to the implementation of the 5E model. Specifically, more emphasis was placed on the explained phase, allowing teachers to delve deeper into the concepts of friction and provide additional examples to clarify understanding. Furthermore, during hands-on activities in the explore phase, teachers played a more active role in guiding students through the experiments, offering support and assistance as needed. These modifications aimed to scaffold student learning and foster a deeper understanding of the scientific principles underlying friction. As a result of these refinements, all students were able to meet the predetermined criteria, indicating the effectiveness of the adapted instructional approach in enhancing science learning outcomes. Table 2 illustrates the comparison between the participants' pre and post-science process skill tests.

Furthermore, upon examining the students' performance in both the initial and final assessments, significant improvements in their science process skills were evident. The study's findings unveiled a noteworthy disparity between the participant's scores in the pre-test ($\bar{x}$ = 7.66, SD = 1.49) and post-test ($\bar{x}$ = 13.44, SD = 1.32), with a t-value of 22.28 and a p-value below 0.00. This considerable increase in scores observed in the post-test strongly suggests that the implementation of the learning management plan had a positive impact on the science process skills of the participants.

Table 2: The comparison between the participants' pre- and post-science process skill tests

Score	n	Mean	SD	T-value	P-value
Post-test	45	13.44	1.32	22.28*	.00
Pre-test	45	7.66	1.49		

*: P>0.05

4.2. The effects of the learning management plan on students' learning achievement of friction

The findings suggest that before the intervention, merely five students (11.10%) met the predetermined passing score of 60% on the friction learning achievement assessment, with an average score of 18.00 (SD = 0). However, post-intervention, all 45 students surpassed the 60% threshold, achieving an average score of 23.15 (SD = 1.84). These results imply a significant improvement in students' science process skills attributable to the implementation of the learning management plan (Table 3).

Furthermore, upon analyzing the student's performance in both the initial and final assessments, significant enhancements in their learning achievement became apparent. The study's results revealed a substantial difference between the participant's scores in the pre-test (mean = 14.13, SD

= 2.50) and post-test (mean = 23.15, SD = 1.84), with a t-value of 17.90 and a p-value below 0.00. This marked improvement in scores observed in the post-test strongly indicates that the implementation of the learning management plan positively influenced the participants' learning achievement in the concept of friction (Table 4).

Table 3: The participants' learning achievement before and after the treatment

Pre-test							Post-test						
n	Passing students			Non-passing students			n	Passing students			Non-passing students		
45	n	x̄ (SD)	%	n	x̄ (SD)	%	45	n	x̄	%	n	x̄	%
	5	18 (0)	11.10	40	13.65(2.25)	88.90		45	23.15 (1.84)	100	0	0	0

Table 4: The comparison between the participants' learning achievement in pre and post-test

Score	n	Mean	SD	T-value	P-value
Post-test	45	23.15	1.84	17.90	.00
Pre-test	45	14.13	2.50		

5. Discussion

The study's results highlight the efficacy of the learning management plan, which was designed based on the principles of 5E inquiry-based learning and STEM education, in enhancing both science process skills and understanding of friction-related concepts. The reason for this success can be explained by examining the underlying characteristics of each strategy. The 5E inquiry-based learning framework provides a methodical yet adaptable approach that enables students to actively participate in scientific principles. By progressing through the stages of engagement, investigation, explanation, elaboration, and evaluation, students not only acquire knowledge but also develop crucial abilities such as observation, analysis, and problem-solving. This structured progression ensures that students are not just passive recipients of information but are actively involved in the learning process, fostering a deeper understanding and appreciation of scientific concepts. Through this engagement, students enhance their critical thinking skills and scientific literacy, which are essential for navigating the complexities of the modern world (Bybee, 2009; Duran and Duran, 2004; Ong et al., 2021).

In addition, the integration of STEM education principles enhances the learning experience by promoting interdisciplinary links and emphasizing practical applications. By integrating science, technology, engineering, and mathematics, students are prompted to investigate the real-world consequences of friction in many situations, ultimately enhancing their comprehension and value of the topic (Khalil et al., 2023; Sen et al., 2018; Ültay et al., 2020). This multidisciplinary approach not only improves students' cognitive capacities but also fosters their creativity, adaptability, and critical thinking skills, all of which are essential for success in a constantly changing environment.

The observation that improving science process skills correlates with enhancing students' comprehension of the concept of friction is a significant finding within this study. This connection highlights the interplay between procedural knowledge and conceptual understanding in science education. By actively engaging in scientific inquiry and experimentation, students not only develop essential skills such as observation, measurement, and data analysis but also deepen their understanding of underlying scientific principles (Kurniawati, 2021; Samputri, 2020). In the context of studying friction, honing science process skills such as observation, experimentation, and analysis directly contributes to students' ability to grasp the intricacies of frictional forces. For instance, as students engage in hands-on activities to explore friction, they are prompted to carefully observe the behavior of objects in various situations, record data accurately, and analyze the factors influencing frictional forces. Through this process, students not only gain practical experience but also internalize fundamental concepts related to friction, such as the factors affecting friction, methods for reducing friction, and the practical applications of friction in everyday life (Yumusak, 2016).

In addition, actively engaging in the scientific inquiry process allows students to cultivate a more profound understanding and recognition of the significance and practicality of scientific principles. Meanwhile, manipulating variables, making predictions, and drawing conclusions based on data also help students develop an understanding of the direct relationship between their actions and the observed consequences. Therefore, this active participation not only promotes comprehension of concepts but also nurtures the development of critical thinking abilities and scientific thinking processes, both of which are crucial for effectively navigating the intricacies of the contemporary world.

The findings of this study align with previous research conducted by Bantaokul and Polyiem (2022), Eroğlu and Bektaş (2022), Manzo et al. (2016), Sen and Oskay (2016), Udonsathian and Worapun (2024), Yakob et al. (2020), and Yonyubon et al. (2022), which have demonstrated the efficacy of employing 5E and STEM education approaches in science education. Corroborating these earlier findings, this study contributes to the existing body of knowledge by providing further empirical evidence supporting the effectiveness of these pedagogical methods in developing science-related skills. Furthermore, this study sheds light on the integration of 5E inquiry-based learning with other instructional methods, showcasing its adaptability and versatility in elementary school science education. The results underscore the potential of incorporating 5E inquiry-based learning alongside other teaching strategies to enhance student's understanding and engagement in science learning.

Moreover, the study highlights the significance of introducing science process skills at the later stages of elementary school education. Demonstrating that students at this developmental stage can effectively acquire and apply science process skills, the study emphasizes the importance of early exposure to inquiry-based learning and hands-on scientific exploration. This insight has implications for curriculum development and pedagogical practices aimed at fostering scientific literacy and competency among elementary school students.

6. Conclusion

In conclusion, this study employed a classroom action research approach to assess the efficacy of a learning management plan integrating 5E inquiry-based learning and STEM education principles in enhancing grade 5 students' science process skills and learning achievement regarding friction within the Thai educational context. The findings demonstrated positive outcomes in both domains, suggesting that the implemented approach effectively contributed to students' learning outcomes. These results hold significant implications for pedagogical practices, highlighting the potential benefits of incorporating innovative instructional methods such as 5E inquiry-based learning and STEM education in elementary science education.

Moving forward, further research is guaranteed to delve deeper into the effectiveness of integrating these instructional approaches into diverse educational contexts and subject areas. Specifically, future studies could explore the long-term effects of such interventions on students' retention of scientific concepts and their ability to apply acquired skills beyond the classroom setting. Additionally, investigating the differential impact of these approaches on student subgroups, such as those with varying academic backgrounds or learning styles, could provide valuable insights into tailoring instructional strategies to meet diverse student needs.

The findings from future research can inform pedagogical practices by highlighting effective methods for fostering deeper understanding and long-term retention of knowledge. Educators can leverage these insights to design and implement instructional strategies that are responsive to the diverse learning needs of their students, thereby enhancing engagement and achievement across various academic disciplines.

The outcomes of such research can also have significant implications for educational policymaking. Policymakers can use the evidence generated to advocate for and develop policies that support the adoption of proven instructional approaches. This could include professional development programs for teachers, the allocation of resources to support innovative teaching methods, and the establishment of guidelines that promote inclusive and differentiated instruction to cater to the diverse student population.

However, it is important to acknowledge the limitations of this study. One notable limitation is the relatively small sample size, which may limit the generalizability of the findings to broader student populations. It would give data that represents the population with a bigger sample size in further studies. Moreover, the lack of qualitative data collection methods restricts the depth of understanding regarding students' experiences and perceptions of the implemented instructional strategies. Future research endeavors should address these limitations by employing larger and more diverse samples, as well as incorporating qualitative methodologies to gain comprehensive insights into the effectiveness and nuances of instructional interventions in science education.

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Compliance with ethical standards

Ethical considerations

Written informed consent was obtained from the parents or guardians of all participants. Participant confidentiality and well-being were prioritized throughout the research process.

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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