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Research Article

Experimental Science Skills of 9th-Grade Students Through Inquiry-Based Learning

Thitisuda Phimthong [1], Prasart Nuangchalerm [1,*], Jutatip Thumsiriwat [1], Jiří Dostál [2], Wee Wongtiankul [3]

[1] Department of Curriculum and Instruction, Faculty of Education, Mahasarakham University, Kham Riang, 44150, Thailand

[2] Department of Technical Education and Information Technology, Faculty of Education, Palacký University Olomouc, Olomouc, 77900, Czech Republic

[3] Department of Management, Faculty of Business Administration, Rajamangala University of Technology Krungthep, Bangkok, 73170, Thailand

*Corresponding Author: Prasart Nuangchalerm, E-mail: prasart.n@msu.ac.th

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Abstract

The research aimed to enhance the experimental science skills of 9th grade students by implementing inquiry-based learning management. Specifically, the goal is for students to achieve a passing score of at least 70% of the total points on assessments. The study involved 20 of 9th grade students from Anukulnaree School, located in Kalasin province, Thailand. The action research focused on the development of students' skills in experimental science, particularly through an inquiry-based approach to learning about the separation of substances. An inquiry-based learning management strategy effectively improved the students' experimental science skills. The research instruments were inquiry-based lesson plan, and experimental science skills test. Each cycle was measured by post-test design. Descriptive statistics were employed for data analysis. The results revealed that 75% of the students met the established criterion of achieving a passing score of 70%. This suggests that the inquiry-based approach was effective in helping students meet the established educational standards.

1. Introduction

Science plays a crucial role in today's global society; it can be impacting everyone's everyday lives and in various professions. It also informs the development of knowledge, technology, and learning tools that people use for daily living. Products of scientific knowledge help our lives be more convenient and response to the higher quality of life (Haleem et al., 2020). This leads to the establishment of an online community and a limitless realm of knowledge, as well as the progress of science and technology. Therefore, 21st century learning requires the ability to adapt to changing circumstances and acquire necessary skills (Prachagool & Nuangchalerm, 2021). Furthermore, the core curriculum strives to address learning management in terms of both content and scientific process abilities. The scientific method and process of science are essentials talent that demonstrates a reasonable and productive thought process. Science helps students and practitioners to comprehend scientific knowledge, learn, and grow into more sophisticated mental processes (McComas, 2020; Armstrong & Green, 2022; Russell & Martin, 2023).

The development of experimental science skills is crucial for students, as it lays the foundation for advanced scientific inquiry and critical thinking. In recent years, educational research has increasingly emphasized the need for effective teaching strategies that not only impart knowledge but also foster practical skills and a deep understanding of scientific concepts (Maddens et al., 2022; Meulenbroeks et al., 2024). Inquiry-based learning emerged as a prominent pedagogical approach that encourages students to engage actively with scientific phenomena. It develops investigative skills in science through exploration and experimentation (Pedaste et al., 2015). Inquiry-based learning is grounded in the constructivist theory of education, which posits that learners construct knowledge through their experiences and interactions with the world (Zajda, 2022).

According to this approach, students are not passive recipients of information but active participants in the learning process. This method has been shown to enhance students' abilities to formulate hypotheses, design experiments, and interpret data, thus improving their experimental science skills. By focusing on student-driven inquiry, educators aim to cultivate a deeper understanding of scientific concepts and develop critical thinking skills that are essential for future scientific endeavors (Bransford et al., 2000). Despite the theoretical advantages of inquiry-based learning, its implementation in secondary education settings presents several challenges. Teachers often struggle with integrating inquiry-based methods into their curricula due to constraints such as limited time, resources, and training (Hofstein & Lunetta, 2003).

Moreover, the effectiveness of inquiry-based learning can vary depending on the students' prior knowledge, motivation, and the support provided by the learning environment (Chen et al., 2023). Addressing these challenges requires careful consideration of instructional design and pedagogical strategies that align with the principles of inquiry-based learning. This paper explores the development of experimental science skills among 9th grade students through the implementation of inquiry-based learning management. This study aims to contribute to a better understanding of how inquiry-based learning strategies can effectively enhance students' scientific abilities and foster a more engaging learning environment by examining their outcomes. The purpose of this endeavor is to develop experimental scientific abilities via inquiry-based learning. It may be better to advise those who are interested to better themselves.

2. Methods

This study employed action research. In the academic year 2023, the study's target group comprised 20 students from Anukulnaree School in Mueang District, Kalasin Province, selected through purposive sampling, based on their experimental science skill score of 70%. The tools used in the research included 6 inquiry-based learning plans, unit the separation of substances, a total time of 11 hours. The experimental science test focused on basic sciences and consisted of 30 questions, 20 real-world requirements, and 10 practice exercises. It is used for testing after the end of each operating cycle. Interview form for experimental science skills is characterized by a semi-structured interview using interviews after the end of each individual operation cycle that does not meet the criteria of 70% of the experimental science skill test.

The foundation for the use of action research in the implementation process (Kemmis & McTaggart, 1998). The research consists of 4 stages- plan, act, observe, and reflect. Based on the action research model, teaching is carried out according to the organizing plan. This research design help students to learn and enhance experimental science skills through action. Also, teachers can develop teaching strategies to help students success in their learning. Teaching follows the action research approach; learning occurs throughout the researcher's learning management process. The experimental behavior of the students was observed. After the end of each operating cycle, students' experimental science skills were measured (Table 1). In addition, data were collected from interviews with students who were the target group.

Table 1. Steps of action research in each cycle

Plan	The researcher collects information by monitoring and assessing students' conduct and learning behavior during classroom activities. To evaluate their experimental abilities, the researchers used a test to measure the students' proficiency in conducting experiments.
Act	Teaching and learning activities are carried out in accordance with the plan for students, utilizing inquiry-based learning management activities that implement techniques of prediction, observation, and explanation.
Observe	After completing the first learning cycle, we measured the students' experimental science skills. We monitored the individual experiments of the target students using an experimental science skills test consisting of 10 questions and a multiple-choice test with 4 choices.
Reflect	The process of inquiry-based learning management involves analyzing the set criteria, conducting student interviews, and reflecting on their learning outcomes. At the end of the operation cycle, the information gathered is used to design new initiatives. They learn in the next operating cycle to be of higher quality.

The researcher assessed the data by evaluating the experimental science skills. The researcher examined experimental science skills. The exam was used to evaluate the students' experimental abilities. Using fundamental statistics, such as average and percentage calculations, to compare with the requirement that pupils have experimental science skills that exceed 70% of the total score. The importance of experimental science skills lies in their ability to experiment and show behavioral signs.

3. Results and Discussion

In the first cycle, the experimental science skill scores obtained by the target students averaged 4.45 out of 10 points, accounting for 44.50%. Six students achieved 70% of the total score, making up 30.00% of the total target group of students. There were 14 students who scored less than 70%, which accounted for 70.00%. The second cycle had an average score of 7.15. This score represents 71.50% of the total number of students. The target group comprises 15 students who achieve a score of at least 70%, making up 75.00% of the total target group of students. Five individuals scored less than 70%, making up 25.00% of the total (Table 2 and Figure 1).

Table 2. Experimental science skills score in each cycle

Students	**First cycle**			**Second cycle**		
	Full score (10)	**%**	**Result**	**Full score (10)**	**%**	**Result**
1	7	70.00	Pass	9	90.00	Pass
2	5	50.00	Fail	8	80.00	Pass
3	1	10.00	Fail	6	60.00	Fail
4	2	20.00	Fail	7	70.00	Pass
5	8	50.00	Pass	8	80.00	Pass
6	2	20.00	Fail	4	40.00	Fail
7	4	40.00	Fail	7	70.00	Pass
8	7	70.00	Pass	9	90.00	Pass
9	5	50.00	Fail	7	70.00	Pass
10	7	70.00	Pass	7	70.00	Pass
11	7	70.00	Pass	9	90.00	Pass
12	5	50.00	Fail	8	80.00	Pass
13	3	30.00	Fail	5	50.00	Fail
14	3	30.00	Fail	7	70.00	Pass
15	4	40.00	Fail	6	60.00	Fail
16	3	30.00	Fail	7	70.00	Pass
17	3	30.00	Fail	8	80.00	Pass
18	4	40.00	Fail	6	60.00	Fail
19	8	80.00	Pass	9	90.00	Pass
20	1	10.00	Fail	6	60.00	Fail
Average	**4.45**	**44.50**	**Fail**	**7.15**	**71.50**	**Pass**

The remarkable increase from 44.50% to 71.50% in the second cycle is noteworthy. It suggests that the intervention or modifications made between cycles improved students' experimental abilities. Students were poor achievers in the first cycle. In the second cycle, 75% were high achievers. After the first cycle, pupils may have adapted and learned because of feedback, additional education, or instructional modifications. Although the proportion of poor achievers fell, 25% still below 70%. This group may require additional assistance in understanding, just like the rest of the class. Although there has been progress, the findings suggest that further effort is necessary to ensure the remaining students can master scientific and experimental science skills.

Inquiry-based learning significantly enhances experimental science skills by encouraging active engagement and critical thinking among students. Research indicates that inquiry-based learning, such as guided inquiry and experiential learning, effectively develops students' scientific competencies (Thanh et al., 2024). A quasi-experimental study (Saleh et al., 2024) demonstrated significant skill improvement in students, linking it to enhanced science process skills. It is also a kind of fostering inquiry and discovery, which leads to better conceptual understanding and active participation in scientific processes (Kotsis, 2024; Wong et al., 2024). While inquiry-based learning shows promise in developing experimental science skills, challenges remain in ensuring that all students reach higher learning achievement.

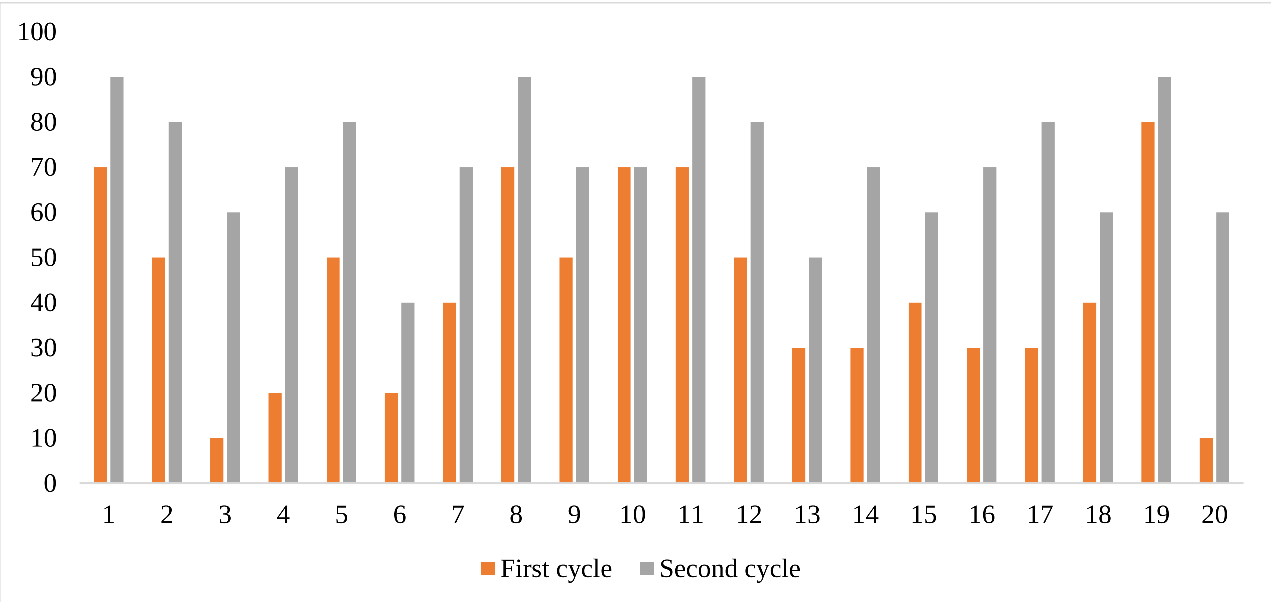

Figure 1. Experimental science skill in each student**,** and in each cycle

The first cycle, a target group of students passed 70% of full score with 6 students, accounting for 30% of the total target group of students.   The score meets the specified criteria and has not yet been met.

This can be explained by the criteria that are inquiry learning is a learning process (Nuangchalerm, 2014). It emphasized the nature of science and emphasis on science process skills (Nuangchalerm, 2013; Prachagool & Nuangchalerm, 2019; Safkolam et al., 2023; Safkolam et al., 2024). This method encourages students to participate in the learning process. It is the process of presenting a situation and predicting what will happen. Students observed the phenomenon through investigation.

However, it was also found that 5 students whose experimental science skill scores have not met the specified criteria is the result of the teacher creating a situation to support the prediction. It does not give students the opportunity to understand the experimental science skills clearly. In the exploration stage, teachers must give students the opportunity to analyze. The process of surveying and examining and encouraging students to use the scientific process to find answers so that students think independently (Ekici & Erdem, 2020).

The results of the study showed that the students had an average of 78.57% experimental science skills, which was very good. As a result, students have improved their academic achievement and experimental science skills. The results of the development of experimental science skills in each operational cycle can be discussed. In the first, they had average score 4.45 out of 10 points, accounting for 44.50% with the number of students in the target group who passed the criteria for 70 percent of the full score. This shows that students had improved their experimental abilities from previous cycles. They improved experimental science skills as well as the inquiry-based inquiry implemented. A few students met the 70% passing threshold, suggesting that most were not doing well. Students meeting the 70% threshold in the first cycle highlight the performance disparity. Although most students initially struggled, the result demonstrates the closure of these gaps. This demonstrates how well the teaching approaches work, particularly in encouraging hands-on learning and skill development through exploration and reflection (Dawes-Duraisingh & Sachdeva, 2021; MacKinnon & Archer-Kuhn, 2023).

In addition, the researchers analyzed the data from the experimental science skill measurement form. It shows the behavior of designing the method of conducting the experiment. Some students showed experimental science skills. However, the students showed fluent behavior while performing the experiment. The least expressive is the conclusion of the experiment results because most of the students copy the data obtained from the experiment results and write their answers without summarizing the results of the experiment. That is, Khumraksa & Burachat (2022) reported that the study offers significant insights into the experimental skills of students. Despite the study's promising results, more research is necessary to confirm the long-term effectiveness of these interventions and to explore the implementation and scaling of these findings in diverse educational contexts. The paper highlights the importance of active, inquiry-based learning methods in fostering science learning, and it makes a strong case for their integration into science education.

The second cycle, the implementation of learning activities gives examples of experiments and allows students to design, discuss, and conduct experiments. Students discuss the results of the conclusion within the group and make adjustments with the guidance of the teacher. The teacher demonstrates/provides enough information in the prediction to perform the performance. The reason for prediction and let the students participate in the discussion of the results together. The scientific experiment skill test, the average score was 7.15 out of 10 points, or 71.50% that meets the requirement of objective. Husni (2020), this study provides evidence that inquiry-based learning can enhance the learning activities and outcomes in school. It helps students gain a deeper understanding of religious subjects. The study advocates for the adoption of this approach in school curricula.

Inquiry-based learning can enhance students' experimental science skills and allow them learn in science and about science (Panjaitan & Siagian, 2020; Sahintepe et al., 2020). This allows students to demonstrate their skills in conducting experiments in accordance with the prescribed sequence of steps and also to carry out experiments. At the same time, the students were very careful to use and store the experimental equipment, and most of the students showed better behavior in recording the results of the experiment. Students use observation skills to record results, which students can record periodically. This pedagogical approach aligns with the nature of science and school science, which is fundamentally about inquiry, exploration, and discovery.

4. Conclusion

In the study's first cycle, only 30% of students met the 70% level of criteria, suggesting early difficulties with experimental scientific abilities. The inquiry learning method emphasizes the development of scientific process skills. Five students failed to meet the requirements because the learning environment did not provide enough opportunities for individual investigation and comprehension.

By the second cycle, the inquiry-based method had greatly enhanced students' experimental abilities.

The average score climbed to 71.50%, indicating more student involvement in conceiving, debating, and carrying out experiments. Teachers' help enabled students to better grasp and modify their predictions, developing autonomous thinking. Overall, students' performance improved, resulting in an average of 78.57% in experimental science skills. The inquiry-based approach was helpful in improving hands-on learning and bridging performance gaps. Students grew more cautious while using equipment, improved their data recording, and demonstrated progress in their scientific inquiry abilities over time. This learning organization help students to learn and meet science as well as experimental science skills developed.

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Declaration of Competing Interest: The authors declare that they have no known competing of interest.

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