The Development of Grade 5 Students' Ability in Making Scientific Explanation on Changes in Matter Using a Brain-Based Learning Approach

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Abstract

This study aimed to examine and compare students' ability to create scientific explanations on changes in matter before and after learning through the Brain-Based Learning (BBL) approach. The study sample consisted of six Grade 5 students enrolled in the first semester of the 2024 academic year at a small-sized primary school under the Udonthani Primary Educational Service Area Office 3, selected through purposive sampling. The research instruments consisted of 5 lesson plans based on BBL and 5 testing situations, which each of these situations was followed by three types of questions: a claim, evidence, and reasoning. The data were analyzed using descriptive statistics, including means, standard deviations, percentages, and frequencies. The research results found that the students had scientific explanation ability after learning higher than before learning. The average scores of the pretest and the posttest were 6.50 (21.67%) and 21.33 (71.11%) respectively. In addition, the students had higher scientific explanation ability in all three components and tend to shift towards a higher level of scientific explanation ability after learning.

Keywords: Brain-based learning; Scientific explanation; Changes in Matter

Introduction

Small-sized schools in Thailand, defined as institutions with fewer than 120 students, face several challenges for promoting student learning achievement because of Resource Limitations. Small schools often grapple with insufficient numbers of teachers and inadequate learning materials, which can hinder effective teaching and learning processes. The Thai government's initiatives to close or consolidate small schools have met with resistance, highlighting the need for policies tailored to the unique contexts of these schools rather than blanket solutions (Kakkaew & Arpamo, 2024). Analyses of Ordinary National Educational Test (O-NET) scores reveal that students in small schools generally perform lower than their peers in larger institutions, particularly in subjects like foreign languages. However, there have been improvements over time, indicating potential for progress (Tussatrin, Nukultham, Kruea-In, & Thongperm, 2014).

These issues necessitate the development of learning approaches that emphasize scientific explanation, which lies at the core of science teaching and learning. Scientific explanation is essential for elucidating natural phenomena and serves as a fundamental component of basic science education. It is also a critical activity embedded within the framework of science instruction. Moreover, it promotes students' understanding of science, enhances their comprehension of the nature of science, and fosters a deeper appreciation of the significance of scientific concepts (McNeill and Krajcik, 2008). Students should understand that empirical evidence is paramount in developing and evaluating scientific explanations. This includes the ability to identify, formulate, and address scientific questions based on empirical evidence. Scientific explanation comprises three key components: claims, evidence, and reasoning. The process of constructing scientific explanations helps students understand how scientific knowledge is acquired, emphasizing the importance of discovery and the effort required to gather evidence or reasoning to support claims. Since evidence and reasoning are integral to forming scientific explanations, the ability to construct such explanations is vital in affirming the credibility of scientific knowledge (Beyer & Davis, 2008).

Based on the researcher's experience in teaching science to elementary students in a small school, it was observed that most students lacked enthusiasm, exhibited boredom, and were unable to provide step-by-step scientific explanations. This resulted in a classroom environment that was not conducive to learning and led to a growing disinterest in science, as students perceived it to be a difficult subject to understand. Furthermore, the Institute for Population and Social Research, Mahidol University (2018), found that critical skills influencing long-term life outcomes include higher-order executive functions involving self-regulation in emotions, thoughts, and actions. These skills, known as Executive Functions (EFs), are crucial for behavior management. When children demonstrate well-developed executive functions, behavioral issues tend to decrease. Studies by the RLG Institute also highlighted the impact of delayed cognitive development in Thai children from early childhood, which subsequently affects their development in later stages, particularly in terms of IQ and EQ. (Hanmaythee, Phitaksinsook, & Aramrit, 2018). As a result, the average O-NET scores have remained below 50%, and Thailand ranked 58th among OECD countries in the PISA assessments (IPST, 2023). This aligns with findings from the Ministry of Public Health, which revealed that Thai children have experienced delayed developmental progress for several consecutive years. This serves as an alarming indicator of the "brain quality" of the nation's future population.

Brain-Based Learning (BBL) is the application of knowledge about the brain and brain functioning systems to design learning processes that align with the developmental stages of the brain at different ages. This approach aims to maximize human learning potential and development, rooted in the science of neuroscience (Jaikam, 2009). Neuroscience provides a framework for understanding the complexities of human thought, facilitating positive societal change. Moreover, neuroscience enables teachers to comprehend the cognitive processes of individual students, allowing them to better fulfill their roles in personalized student development. This is consistent with studies showing that students engaged in brain-based learning combined with concept mapping exhibit progressively higher analytical thinking skills with each assessment (Thamkham, Sliwong, & Suwanachai, 2018). Additionally, students taught using BBL methodologies integrated with visual and auditory media demonstrated superior higher-order thinking skills compared to those taught through traditional methods, with post-test scores significantly exceeding pre-test scores (Marrone, Taddeo, & Hill 2022).

From this rationale and significance, the researchers implemented brain-based learning to enhance the scientific explanation skills of Grade 5 students in the topic of "Changes of matter." It is anticipated that this instructional approach will serve as a model for educators in improving teaching practices, enabling students to develop strong scientific explanation abilities. This, in turn, supports and advances science learning, which is the ultimate goal of science education.

Research Objectives

The objectives of this study were to examine and compare Grade 5 students' ability to create scientific explanations on the topic of 'Changes in Matter' before and after participating in Brain-Based Learning (BBL).

Research Methodology

1. Target Group

The target group for this study consisted of Grade 5 students from a small primary school in Nong Han District, Udon Thani Province, under the Udon Thani Primary Educational Service Area Office 3. During the first semester of the 2024 academic year, a classroom of six students was purposively selected as the research sample.

2. Research Instruments

The research instruments comprised experimental tools and data collection instruments, as detailed below:

2.1 Five lesson plans (15 instructional hours) on "Changes in Matter" were developed using the brain-based learning model by Jensen (2000). The instructional process involved the following five stages: 1) Preparation: Preparing the brain to absorb new information by reviewing prior knowledge and linking it to new concepts. 2) Acquisition: Stimulating the brain to engage with new information through relevant, interesting, and exciting activities. 3) Elaboration: Enhancing intellectual understanding by connecting knowledge through listening, observing, and practicing. 4) Memory Formation: Promoting knowledge retention through repetition and reinforcement in varied contexts. 5) Application: Encouraging students to apply newly acquired knowledge to solve problems in related situations and to summarize the learned content. The quality of these lesson plans was evaluated by three experts. The suitability scores for all five plans were rated with mean scores of 4.87, 4.89, 4.95, 4.94, and 4.94, respectively.

2.2 The scientific explanation assessment tool was developed based on the framework by McNeill and Krajcik (2008). This included claims, evidence, and reasoning. The test consisted of multiple-choice items with four options of science reasoning, scored as follows:

2 points: High performance

1 point: Moderate performance

0 points: Low performance

Each question was designed with scenarios related to the topic of "Changes in Matter," presented through text or images. The tool was validated by three experts for content accuracy, language clarity, and content relevance. The item-objective congruence (IOC) index for all items was 1. The tool was piloted with 18 Grade 5 students from a small school outside the sample group. The quality analysis revealed the difficulty index (p) ranged from 0.31 to 0.75, the discrimination index (r) ranged from 0.25 to 0.88, and the Cronbach's Alpha Coefficient for reliability was 0.85.

3. Data Collection The data collection was conducted in the following steps:

3.1 Pre-Test: Prior to the intervention, the scientific explanation assessment was administered to the target group for one hour, and the data were collected for analysis.

3.2 During Instruction: Brain-based learning activities on "Changes of Matter" were conducted for a total of 15 hours over five weeks using the five lesson plans (three hours per plan).

3.3 Post-Test: After the intervention, the same scientific explanation assessment was administered to the target group for one hour, and the data were collected for analysis.

3.4 Data Analysis: The pre-test and post-test scores were statistically analyzed to study and compare students' scientific explanation abilities.

4. Data Analysis The ability of students' scientific explanation before and after learning with BBL on the topic of changes of matter was presented with the mean score and percentage as follows:

4.1 Students' scientific explanation ability before and after learning with BBL.

Grade 5 Students' scientific explanation ability before and after learning with BBL by taking the pre-test and post-test scores and analyzed using descriptive statistics, including means, standard deviations, percentages, and frequencies. The hypothesis of comparing the post-test scores to the pre-test scores was tested by using the Wilcoxon signed-rank test. The results of data analysis are summarized as shown in Tables 1 and 2.

Table 1: Data analysis results of scientific explanation ability Average and percentage scores before and after learning

Person	Pre-test		Post-test	
	($\bar{x}$)	Percentage	($\bar{x}$)	Percentage
1	10	33.33	24	80.00
2	3	10.00	18	60.00
3	3	10.00	20	66.67
4	9	30.00	23	76.67
5	9	30.00	22	73.33
6	5	16.67	21	70.00
($\bar{x}$)	**6.50**	**21.67**	**21.33**	**71.11**
S.D.	**2.93**		**1.97**	

According to table 1, the mean scientific explanation ability by learning with BBL pretest score obtained by Grade 5 students for overall was 6.50 (21.67%). After learning, their mean posttest score is 21.33 (71.11%). This is a comparison to determine how there is improvement from pretest to posttest; the results reveal that the posttest mean score was higher than the pretest.

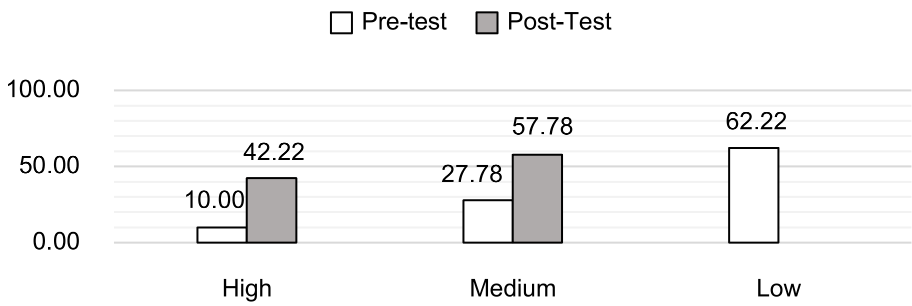

Figure 1. Comparative chart of number of students (percent) and level of ability to explain science in all components.

When categorizing the data into three levels (high, medium, low), as shown in Figure 1, it was found that before the intervention, most students exhibited a low level of ability to make scientific explanations, with only a few students demonstrating medium or high levels of ability. However, after the intervention, none of the students remained at the low level. Instead, the majority of students achieved medium or high levels of ability in making scientific explanations. An example of students' responses before and after learning is illustrated in Table 2, based on the scenario:

"Winner has a bottle of red syrup but wants to make a slushy drink. Winner lowers the temperature of the red syrup by placing the bottle in a bucket of ice and then adding salt, stirring for 5 minutes. Over time, the liquid red syrup in the bottle freezes into ice crystals, becoming a solid."

Table 2 Examples of students' answers on changes in the state of matter.

1.1 Which change is similar to making a slushy red syrup drink (Claim)?

S05	Before learning	A. Making ice cream	Medium
	After learning	D. Formation of hail and making ice cream	High

1.2 How do students know that the change in 1.1 is similar to making a slushy red syrup drink (Evidence)?

S05	Before learning	C. Ice, in a solid state, when left at room temperature, forms into clumps of solid.	Low
	After learning	B. Both making ice cream and hail involve a transition from liquid to solid when the temperature decreases, causing the liquid to freeze into solid clumps.	High

1.3 Why was the change in 1.1 selected (Reasoning)?			
S02	Before learning	"Because reducing the temperature of ice cream causes it to melt similarly to ice."	Low
	After learning	"If a liquid's temperature is reduced, it will solidify into ice clumps."	Medium

4.2 Students' scientific explanation ability before and after learning with BBL for 5 sub topics.

4.2.1 Students scientific explanation ability across all components on the topic of Changes of States of Matter.

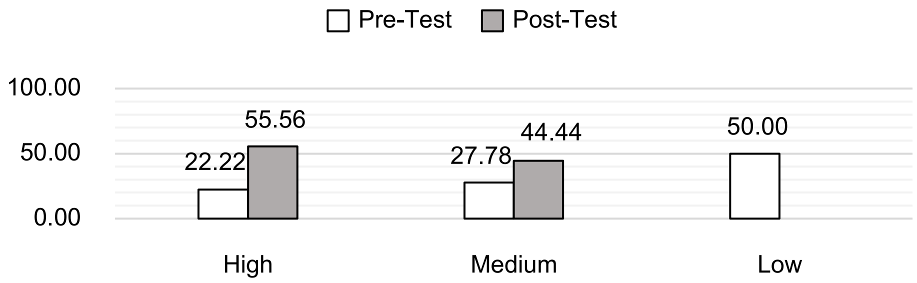

Figure 2: A bar chart comparing the percentage of students at different levels of scientific explanation ability on the topic of Changes of States of Matter.

From Figure 2, it can be concluded that before the intervention, only a few students demonstrated a high or medium ability to explain the phase changes of matter, while most were at a low level. After the intervention, the number of students at the high and medium levels increased, and none remained at the low level.

4.2.2 Students scientific explanation ability across all components on the topic of Sublimation and Deposition.

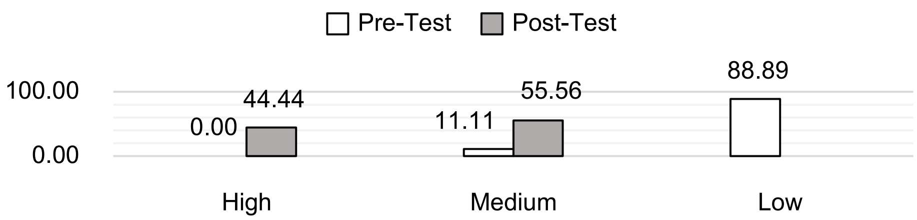

Figure 3: A bar chart comparing the percentage of students at different levels of scientific explanation ability on the topic of Sublimation and Deposition.

From Figure 3, it was found that prior to the intervention, no students demonstrated a high ability to explain sublimation and deposition. Only a very small number of students were at a medium level, while the majority were at a low level. After the intervention, the number of students at the high and medium levels increased, with none remaining at the low level.

4.2.3 Students scientific explanation ability across all components on the topic of Substance Dissolution in Water.

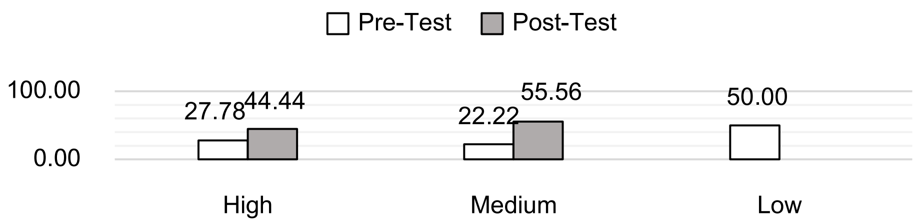

Figure 4: A bar chart comparing the percentage of students at different levels of scientific explanation ability across all components on the topic of Substance Dissolution in Water.

From Figure 4, it was observed that before the intervention, only a few students demonstrated a high or medium ability to explain the dissolution of substances in water, with most students at a low level. After the intervention, the number of students at the high and medium levels increased, with none remaining at the low level.

4.2.4 Students scientific explanation ability across all components on the topic of Chemical Changes.

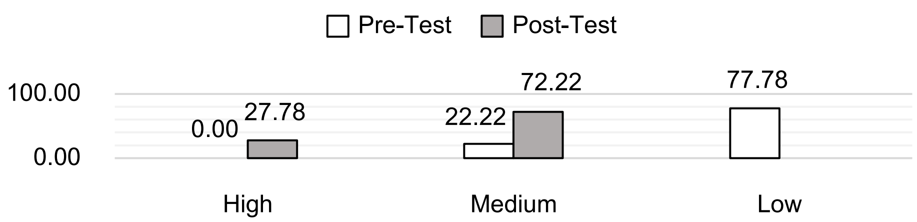

Figure 5: A bar chart comparing the percentage of students at different levels of scientific explanation ability across all components on the topic of Chemical Changes.

From Figure 5, the data indicated that prior to the intervention, no students demonstrated a high ability to explain chemical changes, and only a small number were at the medium level. Most students were at a low level. After the intervention, the number of students at the high and medium levels increased, and none remained at the low level.

4.2.5 Students scientific explanation ability across all components on the topic of Reversible and Irreversible Changes. From Figure 6, concerning reversible and irreversible changes, no students demonstrated a high ability before the intervention. A small number were at the medium level, with the majority at a low level. After the intervention, the number of students at the high and medium levels increased, with none remaining at the low level.

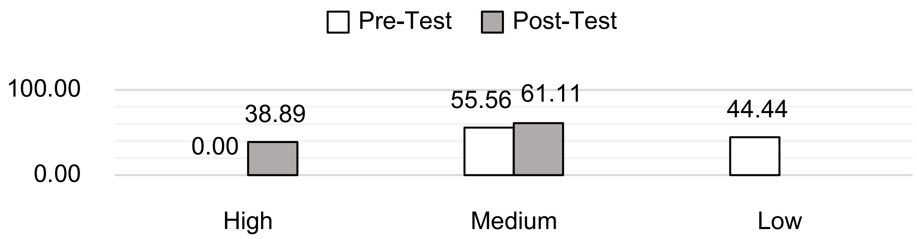

Figure 6: A bar chart comparing the percentage of students at different levels of scientific explanation ability across all components on the topic of Reversible and Irreversible Changes.

Summary

1. Grade 5 students who participated in Brain-Based Learning (BBL) demonstrated improved scientific explanation abilities regarding 'Changes in Matter' across all components. The overall post-intervention average score was higher ($\bar{x}$ = 21.33, 71.11%) than the pre-intervention score ($\bar{x}$ = 6.50, 21.67%).

2. The ability to explain scientific phenomena improved significantly across all subtopics. Before the intervention, only a small number of students exhibited high or medium scientific explanation abilities across the five subtopics, with most students at a low level. After the intervention, the number of students at the high and medium levels increased across all subtopics, and none remained at the low level.

Discussion

The study revealed that Grade 5 students who participated in the Brain-Based Learning (BBL) program demonstrated improved ability to explain the scientific concept of “matter transformation” after the intervention compared to their pre-program performance. This improvement may be attributed to: Students' ability in scientific explanation showed significant improvement across various components. This progress can be attributed to the structured design of Jensen’s brain-based learning model, which enhances cognitive functions and supports the development of scientific reasoning skills (Jensen, 2000). The learning process began with the Preparation phase, incorporating activities such as brain gym exercises, jigsaw puzzles, and games like "Da Vinci Code" to synchronize brain function and promote balanced learning between both hemispheres. These activities helped students feel more relaxed and engaged. In the next phase, students connected new information to their prior knowledge through relevant and stimulating scenarios. Engaging discussions and hands-on experiments further deepened their understanding of scientific concepts. Students then synthesized and organized their acquired knowledge by linking various pieces of information into a structured framework. Through collaborative concept mapping, they systematized their understanding, enhancing long-term memory retention in alignment with the Information Processing Theory. This method allowed students to actively construct meaningful knowledge, making it more accessible for future retrieval and application. In the final stage, they applied their learning to solve problems in novel yet related contexts. By summarizing key concepts, relating them to real-life situations, and tackling new challenges, students reinforced their comprehension and deepened their understanding of the subject matter. These findings are consistent with the research of Kongmun (2020), which showed that students taught using brain-based learning exhibited strong long-term memory retention and achieved academic performance exceeding 70%. Similarly, Phonputtha, Pansuppawat, & Suwannatrai (2021) found that integrating analytical thinking skills and concept mapping within the BBL framework led to improved analytical thinking and academic achievement. Additionally, Marrone, Taddeo, & Hill (2022) reported that students who experienced BBL combined with multimedia demonstrated enhanced higher-order thinking skills and achieved superior post-test scores compared to those taught through traditional methods. Overall, the brain-based learning approach, with its structured and interactive phases, effectively strengthened students' ability to formulate scientific explanations, bridging theoretical knowledge with practical, real-world applications.

Suggestions

1. Future studies could involve a larger and more diverse sample of students from various grade levels and schools to determine if the Brain-Based Learning (BBL) approach has similar effects on a wider range of students.

2. It would be beneficial to assess the long-term impact of the BBL approach on students' ability to make scientific explanations. A follow-up study could evaluate how well the students retain and apply the concepts learned over a longer period.

3. Researchers may explore how the BBL approach can be adapted to other scientific concepts or subjects beyond "matter transformation" to evaluate its effectiveness in promoting scientific reasoning across different topics.

4. It would be useful to compare the effectiveness of BBL with other teaching methods, such as traditional or inquiry-based learning, to see how BBL stands in terms of student engagement, understanding, and academic performance.

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