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ORIGINAL ARTICLE

Investigating the Ability in Constructing Scientific Explanations of Thai Grade 10 Students: Insights from Learning Achievement, Attitude, and School Size

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ABSTRACT

The ability to construct scientific explanations is a vital goal of learning science at all levels. Students from different backgrounds are likely to have this ability differently. This research aimed to assess Thai grade 10 students' ability to construct scientific explanations, examine differences based on learning achievement, attitude toward science, and school size, and find correlations among these variables. The study included 231 students from Phetchaburi province, Thailand, with 77.5% showing moderate ability levels. The research identified significant differences in students' ability levels based on their learning achievement, attitude toward science, and school size. The levels of students' ability correlated with their learning achievement, attitude toward science, and school size. In addition, students with high learning achievement, and positive attitudes, and who attended larger schools tended to have higher ability levels. However, there was no significant relationship between the levels of students' attitudes toward science and school size. These findings highlight the importance of considering individual differences and backgrounds when teaching science, particularly in terms of learning achievement, attitude toward science, and school size.

KEY WORDS: Attitude toward science; learning achievement; school size; scientific explanation; secondary school students

INTRODUCTION

Scientific explanation plays a crucial role in shaping global science education. International reform and standard documents underscore the significance of promoting students' ability to construct scientific explanations as a fundamental aspect of scientific literacy. For instance, the Next Generation Science Standards (NGSS) emphasize the importance of students developing and communicating scientific explanations based on evidence and reasoning (NGSS Lead States, 2013). Similarly, the Framework for K-12 Science Education (National Research Council, 2012) outlines the central role of scientific explanation in the learning progressions across various scientific disciplines. The ability to construct scientific explanations involves the use of claims, evidence, and reasoning to explain scientific phenomena (Mardhiyyah et al., 2022; McNeill and Krajcik, 2008). This process requires students to investigate, analyze, and evaluate evidence and to link it to scientific principles and concepts (McNeill and Krajcik, 2008; National Research Council, 2012; Novak and Treagust, 2018; Sapasuntikul, 2016; Wannathai and Pruekpramool, 2021). Strong abilities to construct scientific explanations are indicative of a deep understanding of scientific principles, phenomena, and knowledge (Novak and Treagust, 2018; Oktavianti et al., 2018). Therefore, developing this skill is essential for students to become proficient in scientific reasoning and to communicate scientific ideas effectively.

The Basic Education Core Curriculum B.E. 2008 and the science learning standards and indicators (Revised edition B.E. 2017) of Thailand emphasize the importance of students having a strong understanding of scientific principles, theories, rules, and laws to be able to explain scientific phenomena correctly and logically (Ministry of Education, 2017). Thus, in Thai classrooms, the introduction of scientific explanations involves the implementation of various pedagogical strategies. Grade 10 students are at the beginning of their upper secondary school studies, where they are expected to develop their knowledge and skills in specific areas and enhance their higher-order thinking abilities to apply these skills at the higher education level (Office of the Education Council, 2013). Previous research studies have consistently shown that Thai Secondary School students have a low ability in constructing scientific explanations, particularly in the reasoning component, with difficulties in giving evidence and reasons to support their claims (Boonrod, 2014; Lertdechapat, 2016; Sapasuntikul, 2016). Although some interventions have led to improvements in their ability levels, students still struggle with providing sufficient scientific data and applying relevant concepts to link the evidence to the claim. Recent research by Janhom and Phornphisutthimas (2020) revealed that upper secondary school students also face challenges in constructing scientific explanations, with incomplete claims and a lack of scientific data and concepts to support their reasoning.

However, little research has specifically focused on the ability of grade 10 students in constructing scientific explanations and the factors that influence their abilities. Understanding these factors is crucial in developing effective teaching strategies to enhance students' scientific explanation skills. Hence, the study of the students' ability in constructing scientific explanations and the study of the correlation of the factors involved in this ability are important goals of this research.

Several studies, including McNeill and Krajcik (2008) and Oktavianti et al. (2018), have shown that there is a correlation between students' ability in constructing scientific explanations and their understanding of scientific concepts. It has been found that students who have a better understanding of scientific concepts tend to have a higher level of ability in constructing scientific explanations. This indicates that students' learning achievement can reflect their understanding of scientific concepts (Cahyono et al., 2016; Kaso et al., 2021; Phye, 1996). Learning achievement is an indicator of the quality of a student's understanding of the knowledge gained after the learning process and experiences. It is commonly measured by test scores (Firman et al., 2020; Phye, 1996). Thus, the levels of learning achievement can serve as an important indicator of the amount of knowledge gained by students through learning. Attitude and school size have been found to impact students' learning achievement in various studies. Research indicates that students who have a positive attitude toward science achieve higher science learning achievement than those who do not (Fulmer et al., 2019; Khotprom, 2018; Mao et al., 2021). Attitude toward science is a complex construct that involves feelings, beliefs, and values about the role of science in society (Fulmer et al., 2019; Mao et al., 2021). It is influenced by a variety of activities, including preferences, and appreciation of science (Fulmer et al., 2019; The Institute for the Promotion of Teaching Science and Technology, 2017). In addition, school size has been found to be a significant factor that affects students' learning achievement in science. Studies have shown that students in smaller schools tend to have higher levels of learning achievement than those in larger schools (Crawford et al., 2016; Riegle-Crumb et al., 2019). This may be because students in smaller schools have more opportunities for individualized attention and support from teachers, as well as greater access to resources and technology.

Considering the school size, research studies have found that school size is classified based on the number of students in the school. In Thailand, there are four officially recognized school sizes: Small (m359 students), medium (360–1079 students), large (1080–1679 students), and extra-large sizes (≥1680 students) (The Office of the Basic Education Commission [OBEC], 2020). Some studies suggest that school size affects students' learning achievement. For example, students in smaller schools have been found to have lower levels of learning achievement compared to those from larger schools (National Reform Steering Assembly, 2016; Sangmahamad, 2017). Moreover, research has shown that a negative attitude toward science is associated with a low level of learning achievement (Fulmer et al., 2019; Khotprom, 2018). However, there is no precise evidence or research study that explicitly shows the impact of school size on students' ability to construct scientific explanations and their attitude toward science. In addition, the relationships between attitude toward science, learning achievement, school size, and students' abilities in constructing scientific explanations are still unclear.

This research aims to contribute to the understanding of Thai grade 10 students' ability to construct scientific explanations by (a) investigating their abilities in constructing scientific explanations, (b) comparing their abilities based on their levels of learning achievement, attitudes toward science, and school size, and (c) exploring the correlations between their ability in constructing scientific explanations, learning achievement, attitude toward science, and school size. The study was conducted in Phetchaburi province, Thailand, which is representative of other provinces in terms of learning and school context. The researcher's familiarity with this province made it a convenient location for the study. The study's results could provide crucial insights for educators and researchers interested in improving students' ability in constructing scientific explanations by identifying areas of concern and the components of scientific explanations where students struggle. Furthermore, the study's findings could guide future research and interventions aimed at enhancing students' ability in constructing scientific explanations and offer an important perspective on the correlations between learning achievement, attitude toward science, school size, and students' ability in constructing scientific explanations.

RESEARCH OBJECTIVES

The objectives of this research are;

1. To investigate Thai grade 10 students' ability in constructing scientific explanations.
2. To compare Thai grade 10 students' ability in constructing scientific explanations based on their levels of learning achievement, attitude toward science, and school size.
3. To explore the correlations among the levels of Thai grade 10 students' ability in constructing scientific explanations, learning achievement, attitude toward science, and school size.

LITERATURE REVIEW

Ability in Constructing Scientific Explanations

The ability in constructing scientific explanations refers to the process by which students can express their understanding of natural phenomena through writing or speaking (Mardhiyyah et al., 2022; McNeill and Krajcik, 2008; Meela and Artdej, 2017; Novak and Treagust, 2018). Constructing scientific explanations requires students to engage in investigative, analytical, and evaluative processes, enabling them to develop a deeper understanding of scientific knowledge related to the given phenomena (Mardhiyyah et al., 2022; McNeill and Krajcik, 2008; Novak and Treagust, 2022). McNeill, Krajcik, and et al. have developed an instructional framework that supports scientific explanations. This framework integrates Toulmin's argumentation model and consists of three components: claim, evidence, and reasoning. A claim is a statement that answers a question, task, or situation. Evidence refers to scientific data or information used to support the claim. Reasoning involves using scientific principles to explain how the evidence supports the claim (McNeill and Krajcik, 2008; Novak and Treagust, 2022; Oktavianti et al., 2018; Wannathai and Pruekpramool, 2021). Scientific explanation and scientific argumentation exhibit distinct characteristics and serve different purposes within scientific inquiry. The scientific explanation involves providing a causal account or understanding of natural phenomena, utilizing models and representations to illustrate underlying mechanisms (McNeill and Krajcik, 2007; Osborne and Patterson, 2011). It aims to deepen comprehension by elucidating why and how a phenomenon occurs. On the other hand, scientific argumentation focuses on justifying claims or persuading others, employing evidence and reasoning to construct and defend arguments (Osborne and Patterson, 2011; Toulmin, 1958).

Constructing scientific explanations is a process that involves generating a claim based on evidence and reasoning (Novak and Treagust, 2022). Evidence can be gathered through observation, measurement, or self-experimentation, but it is crucial to compare and evaluate the reliability and accuracy of the evidence against other sources of data. In collecting evidence, students must consider two important aspects. First, the suitability of the evidence must be relevant to the phenomena or situation being investigated. Second, the sufficiency of the evidence requires multiple pieces of evidence that are strong enough to support the claim (Mardhiyyah et al., 2022; McNeill and Krajcik, 2008; Novak and Treagust, 2022; Oktavianti et al., 2018). By understanding these concepts, students can develop their ability to construct scientific explanations effectively.

Previous research on students' ability to construct scientific explanations consistently revealed that students have a low level of this ability, with the reasoning component being the most problematic (McNeill and Krajcik, 2008; Oktavianti et al., 2018; Traut, 2017). The reasoning component is particularly challenging because students need to link the evidence to the claim by providing appropriate scientific principles and developing this component could enhance students' understanding of science concepts (Lertdechapat, 2016; McNeill and Krajcik, 2008; Meela and Artdej, 2017; Oktavianti et al., 2018). Research conducted in the Thai context has shown similar findings, with Thai students having a low ability in constructing scientific explanations, with the reasoning component being the most challenging (Boonrod, 2014; Janhom and Phornphisutthimas, 2020; Sapasuntikul, 2016). However, the ability to construct scientific explanations is essential for students to learn science at all levels and gain an in-depth understanding of scientific phenomena (Novak and Treagust, 2018; Oktavianti et al., 2018; Zembal-Saul et al., 2013). Therefore, researchers and educators should focus on studying and developing students' abilities in constructing scientific explanations to enhance their scientific literacy.

Learning Achievement

Learning achievement is the outcome of a student's intellectual ability in terms of understanding concepts, performance, and attitude after they have completed a learning task or a course (Cahyono et al., 2016; Kaso et al., 2021; Phye, 1996). It results from gaining direct and indirect experiences through various processes, including the learning process, practice, research, and training (Cahyono et al., 2016; Watthanard et al., 2016). Learning achievement is typically assessed by measuring students' knowledge, attitudes, and skills using various assessment methods such as tests, projects, and assignments (Phye, 1996). In science learning, learning achievement can be measured using tests that assess students' potential in cognitive (knowledge), affective (attitude), and psychomotor (skills) domains of learning behavior (Cahyono et al., 2016; Uttho, 2016). Science learning must be oriented toward the development of scientific literacy, which encompasses students' knowledge, attitudes, and skills related to science (Jufrida et al., 2019). Students who have a strong grasp of scientific principles and concepts will be better equipped to provide accurate scientific explanations using correct scientific concepts and principles (McNeill and Krajcik, 2008). Therefore, it is reasonable to suggest that science learning achievement may be related to student's ability to construct scientific explanations, as students who have a better understanding of science concepts and principles are more likely to construct scientifically sound explanations.

Attitude toward Science

Enhancing attitudes toward science is an important goal of science education research (Fulmer et al., 2019; Mao et al., 2021). Attitude refers to one's feelings, beliefs, and behavioral tendencies that play a crucial role in shaping students' behaviors toward learning. The attitude has three components: Cognitive, affective, and behavioral. The cognitive component consists of beliefs and ideas about something, while the affective component refers to one's feelings and emotions toward it. The behavioral component encompasses one's actions toward it (Wenden, 1991; Zulfikar et al., 2019). Attitude toward science refers to an individual's feelings, beliefs, and behavioral tendencies specifically related to the field of science, encompassing scientific knowledge, methods, and discoveries. It can vary among individuals and is influenced by factors such as education, personal experiences, cultural background, and societal influences. (Osborne et al., 2003). A positive attitude toward science involves strong beliefs in one's ability and can significantly impact students' learning and success (Chen et al., 2018; Pinxten et al., 2014).

Previous research on students' attitudes toward science and their academic achievement has shown that students who have a positive attitude toward science are more likely to have the intention and motivation to learn science, which helps them to see the value in learning science and achieve higher science learning achievements (Fulmer et al., 2019; Khotprom, 2018; Mao et al., 2021). This finding highlights the importance of studying the relationship between students' attitudes toward science and their learning achievements. Moreover, students' learning achievement might also have a relationship with their ability to construct scientific explanations. Therefore, it is essential to investigate the link between students' attitudes toward science and their ability to construct scientific explanations to better understand the factors that can enhance students' learning of science.

School Size

School size is considered one of the indicators of school quality and potential (Gershenson and Langbein, 2015; Hafeez et al., 2020). Larger schools not only differ in terms of student numbers but also offer a greater variety of curricula and learning activities compared to smaller schools (Hafeez et al., 2020). Studies conducted in some countries, such as the United States of America and Pakistan, have revealed a relationship between school size and students' academic achievement, indicating that students who attend smaller schools tend to achieve higher learning outcomes and greater success than those in larger schools, due to the smaller class sizes. Teachers in smaller schools can provide more personal attention to their students in class, which can lead to better outcomes (Bullard, 2011; Egalite and Kisida, 2016; Hafeez et al., 2020; Konstantopoulos and Sun, 2014). In addition, smaller classrooms can be easier to manage and can enhance individual students' achievements and abilities (Filges et al., 2018).

In Thailand, the Ministry of Education has classified schools into four size categories based solely on the number of students they enroll: Small, medium, large, and extra-large (OBEC, 2020). This differs from some other countries that utilize students' socioeconomic status as a criterion for classifying school sizes (Jones and Ezeife, 2011). However, studies on the relationship between school size and students' academic achievement in Thailand have shown different results compared to studies from the United States of America and Pakistan. In Thailand, students in small-sized schools have been found to have lower achievement than those in larger schools (Sangmahamad, 2017). This is due to several problems related to the school management system and government support. Small-sized schools in Thailand receive less development budget from the government, which makes it difficult for them to administer and promote student learning. In addition, there are often not enough teachers to properly manage the classroom and small-sized school teachers are often responsible for teaching multiple subjects outside of their expertise. Finally, students in small-sized schools often come from low-income families and may lack the readiness to learn, leading to low levels of academic achievement (National Reform Steering Assembly, 2016; Rukspollmuang et al., 2017; Sangmahamad, 2017). However, the ability to construct scientific explanations requires accurate knowledge and understanding of scientific principles (Boonrod, 2014; McNeill, 2012). Therefore, low levels of academic achievement in small-sized schools may also affect students' ability to construct scientific explanations.

METHODOLOGY

Research Design

In this study, a cross-sectional survey design was employed to achieve three main objectives: First, to investigate Thai grade 10 students' ability in constructing scientific explanations; second, to compare this ability based on their levels of learning achievement, attitudes toward science, and the size of their schools; and third, to explore the correlations among these variables. This design facilitated the efficient gathering of data from diverse samples at a single point in time, allowing for the examination of differences and relationships across various groups (Creswell and Creswell, 2018).

Study Group

The population for this study was the 2825 grade 10 students who were enrolled in the first semester of 2019 in Phetchaburi Province, Thailand (Retrieved from the Office of Education, Phetchaburi Province on June 10, 2019). Table 1 displays the general information of the students. A stratified sampling method was used to select 231 students, including those from large, medium, and small-sized schools. The sample size was determined using Yamane's formula, with a 5% sampling error, and the appropriate sample size was 350 students. However, the response rate was 66.0%, resulting in only 231 students participating in the study.

Research Instruments

This survey was divided into two parts. The first part aimed to collect general information about the samples, including their levels of learning achievement (high, moderate, and low), school sizes (large, medium, and small), and attitudes toward science. The students' attitude toward science was measured using a Likert Scale (very high, high, moderate, low, and very low). The content validity evidence was verified by three experts using the index of consistency (IOC), and the IOC mean scores from the experts for all items equaled 1.0. In the second part, we assessed the ability of Thai grade 10 students in constructing scientific explanations by administering a subjective test. An example of the ability in constructing scientific explanations tests can be seen in Figure 1. The test consisted of 10 questions with non-specific scientific content, and each question provided sufficient scientific information, such as concepts and principles, to guide students in writing a complete scientific explanation. Students were free to write their answers to the guideline questions.

The test's content validity evidence was verified by three experts, and the mean IOC scores from the experts for all questions equaled 1.0. The appropriateness of the language usage and utility of the test and the scoring rubrics were also evaluated and received a very high level of rating (M = 5.0) for all questions. The difficulty (p) and discrimination (d) indices for each question were calculated using Whitney and Sabers'

Table 1: General information of students

School sizes	Learning achievement	Attitude toward science				Total (%)
		Low (%)	Moderate (%)	High (%)	Very high (%)	
Small (≤359 students)	Low (GPA <2.0)	2 (3.6)	1 (1.8)	1 (1.8)	-	4 (7.1)
	Moderate (2.0 ≤GPA ≤3.0)	2 (3.6)	10 (17.9)	5 (8.9)	-	17 (30.4)
	High (GPA >3.0)	-	7 (12.5)	22 (39.3)	6 (10.7)	35 (62.5)
	Total	4 (7.1)	18 (32.1)	28 (50.0)	6 (10.7)	56 (100.0)
Medium (360–1,079 students)	Low (GPA <2.0)	-	-	-	-	-
	Moderate (2.0 ≤GPA ≤3.0)	-	18 (24.7)	7 (9.6)	1 (1.4)	26 (35.6)
	High (GPA >3.0)	-	18 (24.7)	20 (27.4)	9 (12.3)	47 (64.4)
	Total	-	36 (49.3)	27 (37.0)	10 (13.7)	73 (100.0)
Large (1,080–1,679 students)	Low (GPA <2.0)	-	1 (1.0)	-	-	1 (1.0)
	Moderate (2.0 ≤GPA ≤3.0)	1 (1.0)	9 (8.8)	8 (7.8)	1 (1.0)	19 (18.6)
	High (GPA >3.0)	1 (1.0)	33 (32.4)	37 (36.3)	11 (10.8)	82 (80.4)
	Total	2 (2.0)	43 (42.2)	45 (44.1)	12 (11.8)	102 (100.0)
Total	Low (GPA <2.0)	2 (0.9)	2 (0.9)	1 (0.4)	-	5 (2.2)
	Moderate (2.0 ≤GPA ≤3.0)	3 (1.3)	37 (16.0)	20 (8.7)	2 (0.9)	62 (26.8)
	High (GPA >3.0)	1 (0.4)	58 (25.1)	79 (34.2)	26 (11.3)	164 (71.0)
	Total	6 (2.6)	97 (42.0)	100 (43.3)	28 (12.1)	231 (100.0)

"Minerals are naturally occurring inorganic substances composed of atoms of one type of element or two or more elements arranged in a definite crystalline structure. They are solid in nature and possess specific chemical formulas and physical properties. Therefore, minerals of the same type exhibit similar physical properties. Different minerals may share certain similar physical properties. Identifying the type of mineral requires the utilization of data obtained from multiple tests on various properties of the mineral, such as color, streak, hardness, and density, etc."

The geologist collected samples of five different minerals and studied the physical properties of each mineral, with the results as shown in the table below:

Mineral	Mass (g)	Density (g/cm^3)	Color	Streak	Hardness
A	30	2.70	White	White	3
B	30	2.75	Black	Brown	5
C	17	2.70	White	White	3
D	17	3.00	Gray	Gray	3

Write a scientific explanation to state that: **"Which minerals are of the same type? What data do you consider?** and **What is your reason?"**

Figure 1: Example of ability in constructing scientific explanation test

method, and the values were found to be in an appropriate range (p = 0.26–0.47, d = 0.52–0.93) (Whitney and Sabers, 1970). In addition, the Cronbach's alpha reliability coefficient of the test was found to be very high (r = 0.87). Hence, the test's validity and reliability evidence were within the appropriate range for implementation (Lester et al., 2014).

Data Collection

The study collected data on students' levels of learning achievement, attitude toward science, and school sizes, as well as their ability to construct scientific explanations using a 10-question test. The test lasted 120 min, and students' explanations were scored based on a specific rubric adapted from McNeill and Krajcik (2008). An example of the scoring rubrics for each scientific explanation component can be seen in Figure 2. The rubric consisted of three components (claim, evidence, and reasoning) and three levels of scoring for each component (0, 1, and 2), resulting in a six-point score for each question.

Data Analysis

The general information of the samples was analyzed using frequency and percentage. The overall scores of students' ability to construct scientific explanations were analyzed using the mean and standard deviation (the test consisted of ten questions with a total score of 60). The researcher divided the total scores into three levels ability to construct good scientific explanations (score 41–60), moderate (score 21–40), and unsatisfactory levels (score 0–20). Then, the students' scores were classified into these three levels. Furthermore, considering each component of the scientific explanation: Claim, evidence, and reasoning, the scores were separately analyzed using frequency and percentage to present the number of students in each level of each component.

The differences in the mean rank of Grade 10 students' ability to construct scientific explanations, compared to their different levels of attitude toward science, learning achievement, and school size, were analyzed using the Kruskal–Wallis test (H) due to the non-normal distribution of all data. The correlations between Grade 10 students' ability to construct scientific explanations, learning achievement, attitude toward science, and school size were analyzed using the Spearman rank correlation coefficient (r_s), considering all variables at the ordinal scale of measurement level (Pagano, 2012).

RESULTS

Thai Students' Ability in Constructing Scientific Explanation

Table 2 displays the maximum and minimum scores, as well as the means and standard deviations of students' ability in constructing scientific explanations. After assessing the ability of 231 grade 10 students to construct scientific explanations, the results showed that most students (77.5%) had a moderate level of proficiency, while only a small number (6.9%) demonstrated good proficiency.

The students' ability to construct scientific explanations was evaluated based on three components: Claim, evidence, and reasoning. Table 3 presents the numbers and percentages of students in each component. The results indicated that most students (69.7%) were at a good level in the claim component. However, for the evidence component, most students (59.3%) demonstrated an unsatisfactory level of proficiency. Similarly, for the reasoning component, most students (63.1%) displayed an unsatisfactory level of proficiency.

The examples of students' responses in Figure 3 found that the students with a good level of ability made an accurate claim about A and C. They provided appropriate evidence (streak, density, and hardness) and reasoned that minerals of the same type have similar physical properties. The student with a moderate level of ability made an accurate claim, supported by evidence but lacking additional details. Their reasoning might serve as evidence. The student with an unsatisfactory level of ability made an inaccurate claim about C. They did not provide evidence and their reasoning may still be considered as evidence.

The Comparisons of Thai Grade 10 Students' Ability in Constructing Scientific Explanation with the Different Levels of Learning Achievement, Attitude Toward Science, and School Sizes

The results of comparing the mean rank of grade 10 students' ability in constructing scientific explanations with their levels of learning achievement (high, moderate, and low) as can be seen in Table 4 revealed significant differences (H [2, n = 231] = 38.363, p = 0.000) in the mean rank of these students' ability across different levels of learning achievement. Students with high levels of learning achievement (M = 30.4) demonstrated a higher level of ability in constructing scientific explanations compared to those with moderate (M = 24.2) and low levels (M = 5.6) of learning achievement.

Similarly, when comparing the mean rank of grade 10 students' ability in constructing scientific explanations with their levels of attitude toward science (very high, high, moderate, and low), significant differences (H [3, n = 231] = 10.999, p = 0.012) were observed across different levels of attitude toward science. Students with very high (M = 30.8), high (M = 28.9),

Components	Score		
	0	1	2
Claim	No claim is made, or an incorrect claim is made. For example, "All minerals/there are no minerals the same type" or "identify other minerals not A and C."	Makes an accurate claim but is unclear. For example, "There are two minerals that belong to the same type."	Makes an accurate claim. For example, "A and C are the same type".
Evidence	No evidence is provided, or incorrect evidence is provided by indicating that "mass" is a property that should be considered together.	Provides appropriate evidence but is insufficient, as it only provides information on streak, density, or hardness. For example, "A and C have the same streak" or "A and C have the same density."	Provides appropriate and sufficient evidence, consisting of streak, density, and hardness. For example, "A and C have the same streak, density, and hardness."
Reasoning	No reasoning is provided, or reasoning is provided using incorrect scientific principles. For example, "The same type of minerals will have the same mass" or providing a more general reasoning, such as "Both types of minerals yield similar test results".	Provides reasoning by repeating the evidence. For example, "A and C have the same streak, density, and hardness" or indicating that they are the same type of mineral.	Makes accurate reasoning that "The same type of minerals will have similar physical properties."

Figure 2: Example of scoring rubrics for each scientific explanation component

Table 2: Students' ability to construct scientific explanations

Levels of students' ability in constructing a scientific explanation	n (%)	Total scores	Max.	Min.	M	Standard deviation
Good	16 (6.9)	60.0	54.0	41.0	43.7	3.4
Moderate	179 (77.5)	60.0	40.0	21.0	29.7	5.1
Unsatisfactory	36 (15.6)	60.0	20.0	0	13.7	7.0
Overall	231 (100.0)	60.0	54.0	0	28.2	8.9

Table 3: Numbers and percentages of students in each component

The components of scientific explanation	The numbers and percentages of grade 10 students		
	Good level (%)	Moderate level (%)	Unsatisfactory level
Claim	161 (69.7)	7 (3.1)	62 (26.9)
Evidence	80 (34.6)	14 (6.2)	137 (59.3)
Reasoning	61 (26.4)	24 (10.5)	146 (63.1)

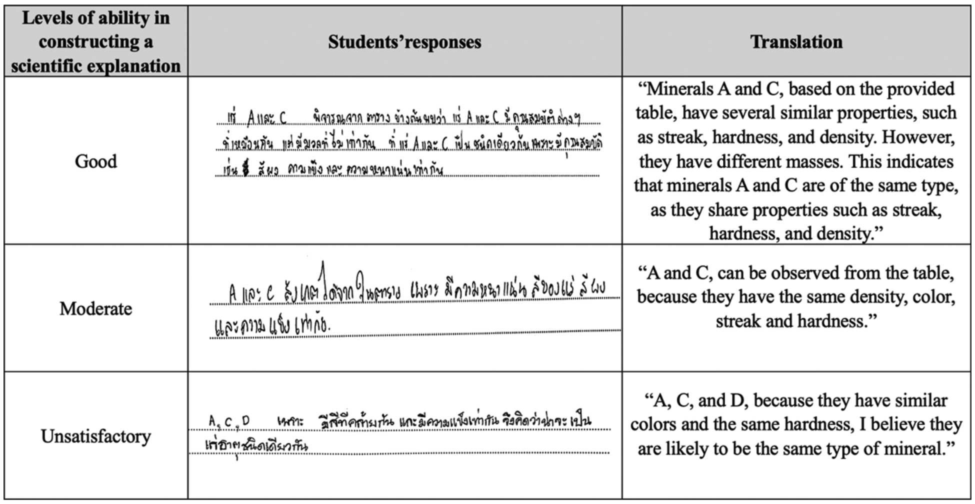

Figure 3: Examples of students' responses

and moderate levels (M = 27.7) of attitude toward science displayed a higher level of ability in constructing scientific explanations than those with a low level (M = 13.3) of attitude toward science.

Furthermore, significant differences (H[2, n = 231] = 79.785, p = 0.000) were found in the mean rank of students' ability to construct scientific explanations across different school sizes (large, medium, and small). Students in large (M = 32.2) and medium-sized schools (M = 29.8) demonstrated a higher level of ability in constructing scientific explanations compared to those in small-sized schools (M = 18.8).

The Correlations between the Levels of Students' Ability in Constructing Scientific Explanation, Learning Achievement, Attitude Toward Science, and School Sizes

The correlations between students' ability levels in constructing scientific explanations, learning achievement, attitude toward science, and school size are presented in Table 5. A low positive correlation (r_s = 0.356) at the 0.05 level of statistical significance was found between students' ability levels in constructing scientific explanations and learning achievement. Conversely, a very low positive correlation (r_s = 0.188) at the 0.05 level of statistical significance was found between students' ability levels in constructing scientific explanations and attitudes toward science. Moreover, the correlation between students' ability levels in constructing scientific explanations and school size was medium positive (r_s = 0.408) at the 0.05 level of statistical significance. The results also indicated low positive correlations between students' learning achievement and their attitude toward science and school size (r_s = 0.310 and 0.184, respectively) at the 0.05 level of statistical significance. Notably, there was no relation found between students' attitudes toward science and school size.

DISCUSSION

The findings of this study indicate that Thai grade 10 students face difficulties in constructing scientific explanations, as most of them (77.5%) were only at a moderate level of ability, and only a few (6.9%) were at a good level. When examining the components of scientific explanation, it was found that most students (69.7%) were able to make accurate claims, indicating that generating an answer to a question was not a challenging task for them. The claim is often considered the easiest component, and students can draw on their prior knowledge to formulate a response (Farida et al., 2021; Lertdechapat, 2016; McNeill and Krajcik, 2007; Meela and Artdej, 2017). In addition, students were able to accurately determine if they understood the question being asked (Gotwals and Songer, 2013), which could have contributed to the high scores received in this component. On the other hand, most students were at an unsatisfactory level in the evidence and reasoning components.

The survey results showed that the evidence and reasoning components were the most challenging for Thai grade 10 students, as their mean scores were unsatisfactory. In the evidence component, many students were only able to provide a claim without appropriate supporting evidence, while some provided incorrect evidence. This indicates that providing

Table 4: Mean rank comparisons between variables

Variables	Levels	n	M	Standard deviation	Mean rank	H	p-value	Pairwise comparison	Adj. Sig.
Learning achievement	Low	5	5.6	8.4	9.4	38.363*	0.000	Low–High	0.000
	Moderate	62	24.2	8.8	82.0			Low–Moderate	0.058
	High	164	30.4	7.4	132.1			Moderate–High	0.000
Attitude toward science	Low	6	13.3	12.6	38.2	10.999*	0.012	Low–Moderate	0.050
	Moderate	97	27.7	9.4	112.3			Low–High	0.024
	High	100	28.9	7.3	118.9			Low–Very high	0.007
	Very High	28	30.8	8.9	135.4			Moderate–High	1.000
								Moderate–Very high	0.641
								High–Very high	1.000
School sizes	Small	56	18.8	8.5	48.4	79.785*	0.000	Small–Medium	0.000
	Medium	73	29.8	5.3	125.9			Small–Large	0.000
	Large	102	32.2	7.5	146.1			Medium–Large	0.146

*p<0.05, n_{total}=231

Table 5: Correlations between variables

Variables	A	B	C	D
Levels of students' ability in constructing scientific explanation (A)	1.000	0.356*	0.188*	0.408*
Levels of learning achievement (B)		1.000	0.310*	0.184*
Levels of attitude toward science (C)			1.000	−0.002
School sizes (D)				1.000

*p<0.05

appropriate evidence was a difficult task for students, and they struggled with this component. The evidence component requires students to analyze scientific information and data to support their claims, which can be a complex process (McNeill, 2012; Meacham, 2017). Gotwals and Songer (2013) also highlighted the difficulty that students face in providing sufficient and appropriate evidence to support their claims. Lack of understanding of scientific concepts, inability to analyze data, and inability to explain their findings can lead to inaccurate evidence in scientific explanations (Farida et al., 2021; Janhom and Phornphisutthimas, 2020).

The reasoning component was found to be the most challenging for students, as they struggled to provide scientific principles to support their explanations. In some cases, students even used incorrect scientific principles to provide reasoning, highlighting a lack of understanding of scientific concepts. This problem is not unique to Thai students. Studies conducted in other countries have also shown that students struggle with constructing scientific explanations, particularly in the reasoning component (Oktavianti et al., 2018; Sapasuntikul, 2016; Traut, 2017). As noted by Gotwals and Songer (2013), providing reasoning is more difficult than claim and evidence, as it requires students to demonstrate an understanding of scientific principles and concepts.

The findings revealed significant differences in the mean rank of students' ability to construct scientific explanations based on their level of learning achievement. Specifically, students with high learning achievement demonstrated a stronger ability to construct scientific explanations than students with moderate and low learning achievement. Previous research suggests that learning achievement reflects a student's comprehension, performance, skills, and attitude after learning (Cahyono et al., 2016; Kaso et al., 2021; Phye, 1996). Therefore, high learning achievement students may have a stronger understanding of scientific principles, theories, and laws related to the contents. They can use this understanding as evidence and reasoning to support their scientific explanation, which contributes to their higher ability in constructing scientific explanations (Boonrod, 2014; Janhom and Phornphisutthimas, 2020; McNeill, 2012). According to a study by Gotwals and Songer (2013), lower-achieving students were less likely to include sufficient and appropriate evidence than higher-achieving students in constructing scientific explanations. This finding suggests that higher learning achievement is linked to a higher level of ability in constructing scientific explanations. In addition, students with a positive attitude toward science were found to have a higher level of ability in constructing scientific explanations than those with a low level of attitude. A positive attitude toward science is linked to increased motivation and intention to learn and acquire knowledge, which can lead to higher science learning achievements (Bal-Taştan et al., 2018; Fulmer et al., 2019; Khotprom, 2018; Mao et al., 2021). These results are consistent with previous studies that found a positive correlation between positive attitudes, higher learning achievements, and a higher ability in constructing scientific explanations (Berger et al., 2020; Chen et al., 2018).

The results of the study showed that the size of schools had a significant effect on students' ability in constructing scientific explanations. Specifically, students in large and medium-sized schools demonstrated a higher level of ability than students in small-sized schools. In Thailand, smaller schools often face challenges in promoting student learning achievement and quality despite receiving government development budgets. The shortage of teachers, especially those teaching specific subjects, is a major issue. In addition, students in small-sized schools typically come from low-income families and lack access to learning equipment and facilities. These factors contribute to their lower level of learning readiness and consequently, their ability to construct scientific explanations (Aranyawet et al., 2017; National Reform Steering Assembly, 2016; Poomali et al., 2014; Sangmahamad, 2017). This finding is consistent with previous studies that reported the same results (Jayawardena et al., 2020; Jetu and Wariso, 2019; Todla, 2023).

In correlational analysis, the findings suggest that students with higher levels of learning achievement may have a higher level of attitude toward science and a higher level of ability in constructing scientific explanations. This may be because constructing scientific explanations requires accurate scientific concepts, and students with higher levels of learning achievement and attitude toward science may have a better understanding of these concepts. As a result, they may be able to construct better scientific explanations compared to students with lower levels of learning achievement. In addition, the study found a medium positive correlation between students' ability levels in constructing scientific explanations and school sizes, which was higher than other variables. The levels of learning achievement and school sizes also had a low positive correlation with each other. These findings suggest that larger schools may provide better opportunities for students to improve their abilities in constructing scientific explanations and achieve better learning outcomes in science than smaller schools. This highlights the issue of educational inequality in Thailand, where smaller schools may face challenges in providing sufficient resources and opportunities for their students.

This research also discovered that there was no correlation between students' attitudes toward science and school sizes. Therefore, it can be inferred that the size of schools may not be a significant factor in shaping students' attitudes toward science. Other factors, such as teaching methods and teachers, could have a more significant impact. Students who learn with effective and engaging teachers are likely to have a positive attitude toward science. This is because these teachers can utilize hands-on activities, provide clear examples, encourage collaboration, incorporate indigenous knowledge systems, and design a science curriculum that is relevant to students' lives (Deborah and Kioko, 2012). Thus, even if students attend small-sized schools, having good administration and teachers who use effective teaching methods can promote a positive attitude toward science.

CONCLUSION AND RECOMMENDATION

The study reveals that constructing scientific explanations is a challenging task for most Thai grade 10 students, particularly regarding providing evidence and reasoning components. However, students who demonstrated higher academic achievement, positive attitudes toward science, and attended larger schools tended to perform better in constructing scientific explanations. There are several limitations to this study. First, the findings of this study are specific to Thai grade 10 students and may not be applicable to students in other grade levels or countries. Second, the study relied solely on self-reported measures and did not incorporate other assessment methods, such as observations or interviews. This limited the depth of understanding regarding students' abilities and attitudes toward science. In addition, the study did not account for external factors that could potentially influence students' abilities and attitudes toward science, such as the home environment, parental involvement, or prior science learning experiences. However, it is important to note that this research focused exclusively on government schools. Conducting a study that includes private schools would provide a clearer overview of the ability to construct scientific explanations among grade 10 students. To address the mentioned limitations, further studies could be conducted. Comparative studies involving students from different school types, grade levels, and countries would enable researchers to examine the generalizability of the findings and provide a more comprehensive understanding of students' abilities across diverse educational contexts. Combining self-reported measures with additional assessment methods, such as observations or interviews, would enhance the understanding of students' abilities. Exploring the influence of external factors on students' abilities and attitudes toward science should be investigated to gain a deeper understanding of the contextual influences affecting students. The findings of this study provide valuable insights for educators and policymakers, as they can use this information to develop effective interventions and create a conducive learning environment that promotes students' ability to construct scientific explanations. By implementing these recommendations, educators and policymakers can facilitate the growth and development of students' scientific reasoning, ultimately enhancing their overall scientific literacy.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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