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Thai Seventh-grade Students' Awareness of and Ability to Formulate Scientific Hypothesis

태국 7 학년 학생의 과학적 가설에 대한 인식과 가설 설정 능력 조사

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서울대학교 대학원

과학교육과 생물전공

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지도 교수 김 영 수

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서울대학교 대학원
과학교육과 생물전공
Patcha Dokmai

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2017 년 7 월

위 원 장 _____(인)
부위원장 _____(인)
위 원 _____(인)

ABSTRACT

Thai Seventh-grade Students' Awareness of and Ability to Formulate Scientific Hypothesis

Patcha Dokmai

Department of Science Education (Biology Major)

The Graduate School

Seoul National University

The purpose of this study was to survey the Thai seventh-grade students' awareness of and ability to formulate a scientific hypothesis. A total of 285 Thai seventh-graders from three Thai public schools were asked to respond the questionnaire Awareness of and Ability to Formulate Scientific Hypothesis (Thai version).

The results of Thai seventh-grade students' awareness of 'nature of scientific knowledge' and 'scientific method' indicated that, firstly, the students were aware that scientific knowledge (1) is created from the valid grounds, (2) is incomplete, (3) can be changed. Moreover, they thought that the scientific knowledge is not created by scientists but discovered by scientists. Secondly, most of the students have heard the scientific method terms namely 'hypothesis', 'prediction', and 'conclusion' while only a half of them have heard about

‘assumption’. They thought that they understood well in all scientific method terms except in ‘assumption’. Moreover, the students could not distinguish ‘hypothesis’ from ‘prediction’ in many cases.

For the results of Thai seventh-grade students’ awareness of scientific hypothesis, the students were aware that hypothesis (1) is formulated from the valid grounds, (2) must be verified, (3) is a testable statement, (4) is incomplete, and (5) can be changed. Moreover, they were unaware with the idea that the hypothesis is stated by showing the relationship between independent and dependent variables.

Lastly, results of Thai seventh-grade students’ ability to formulate a scientific hypothesis, the students had an ability to formulate a hypothesis as an answer to inquiry question and state a hypothesis which presented only one independent variable. Moreover, they could formulate a testable hypothesis. The students were able to present the valid grounds which they used to formulate the hypothesis. However, they lacked ability to formulate a generalizing hypothesis. Hence, we can state that Thai seventh-grade students understood in a hypothesis but they did not perform well on formulating a hypothesis.

Regarding the results of this study, we can conclude that Thai seventh-grade students need more practice in the variable extraction process. Particularly, a new teaching method for enhancing students’ awareness of and ability to formulate a scientific hypothesis is required to be developed.

Keywords: nature of science, scientific method, science process skills, experiment, hypothesis, prediction, Thai middle school student, awareness

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I. INTRODUCTION

1. Research Significance

Science and technology play an increasingly important role in our present and future, as it concerns every sphere of our life. Even though rapid development in science and technology make our life easier, more comfortable and longevity, it brings us faces many new problems including environment, society, and culture. Therefore, all of us need to be provided with promoting critical thinking, creativity and problem-solving that are important skills for livelihood. For this reason, scientific literacy is regarded as an ultimate goal of science education reform in Thailand and many countries (Institute for the Promotion of Teaching Science and Technology, 2013) because it provides students to have the abilities to make an informed decision when they face the scientific issue, personal and social problem (Flick & Lederman, 2004).

In fact, nature of science (NOS) and scientific inquiry are acknowledged as a critical component of scientific literacy (Lederman, 1992) and had been introduced in the school science more than ten years. (National Research Council, 1996; American Association for the Advancement of Science, 1999). Teaching nature of science increases learners' apprehension about the body knowledge of science because the learners will understand the limitations and strengths of scientific knowledge, develop various aspects of scientific attitude (Lederman, 2007), and also understand how the scientific knowledge is generated (Lederman, 1992). In contrast, scientific inquiry enables students to have authentic experiences of scientist and know how to generate scientific knowledge. Promoting students to understand nature of science is to teach them through scientific inquiry. This point is compatible with Peter (2006) who

suggested that quality inquiry investigations can be implemented by using the aspects of the nature of science as a guideline. Moreover, the scientific inquiry may provide a critical context for discussion and reflection within which learners can more fully develop an understanding of nature of science (Schwab, 1962).

In Thailand, teaching inquiry is demonstrated by the hypothetico-deductive model as presented in the learning objective of the grade level indicator section (Ministry of Education, 2008) and all standard science textbooks as speculated in the science learning area in Basic Education Core Curriculum B.E. 2551. This inquiry model is mainly concentrated on designing the experiment and validating a hypothesis by experimental results. Many educators agree that hypothesis, which is tentative answer to inquiry problem (Kim, 2010) or possible solutions to question or problem (Wenham, 1993), is an important prerequisite of scientific method because it provides a key which we have to follow to find the answers. Moreover, it leads to the experimental design, develops new theories (Lawson, 2000), and generate the new scientific knowledge. From this sense, we can conclude that formulating hypothesis is the heart of scientific method. Therefore, the ability to formulate the hypothesis is an essential skill to promote among the students. Moreover, it is generally accepted that creativity is important for hypothesis generation (Lin, 2003).

Even though hypothesizing is an important key in scientific method, previous studies have indicated that students lacked the ability to formulate a hypothesis (Peter, 1992; German & Odom, 1996). Likewise, previous studies reported that Thai students lacked integrated science process skills, especially ability to formulate the hypothesis (Singpun, 2000; Nakthong, 2007; Plagsri, 2010). However, the majority of studies in Thailand is about basic science process skills while the scientific hypothesis is still scanty, particularly the studies about awareness of scientific hypothesis.

According to Basic Education Core Curriculum B.E. 2545, Thai seventh-grade students are aimed to thoroughly study scientific method (Ministry of Education, 2008). Moreover, the Middle School 1 Science Textbook (standard science textbook) indicates that Thai seventh-grade students have to thoroughly study scientific method to have the prerequisite knowledge in the higher grade and in their everyday lives (IPST, 2013). As mentioned above, the teaching of scientific method in Thailand place importance on designing the experiment and validating a hypothesis by experimental results so the ability to formulate the hypothesis is a necessary skill required for the students. In fact, in formulating a good hypothesis, students need to understand about its basic aspects. Therefore, the purpose of this study was to survey the Thai seventh-grade students' awareness of and ability to formulate a scientific hypothesis. Additionally, awareness of nature of scientific knowledge and scientific inquiry were included in this survey. The research contents of this study were as follows.

1. Awareness of nature of scientific knowledge
2. Awareness of scientific method
3. Awareness of scientific hypothesis
4. Ability to formulate scientific hypothesis

2. Purpose of the Study

The purpose of this study was to survey Thai seventh-grade students' awareness of and ability to formulate a scientific hypothesis. The results of this study can be used to design and improve the strategies for teaching science and students' skill in formulating a hypothesis.

3. Scope of the Study

The contents of this study are as follows:

1) Research on the Thai seventh-grade students' awareness of nature of scientific knowledge.
2) Research on the Thai seventh-grade students' awareness of scientific method.
3) Research on the Thai seventh-grade students' awareness of scientific hypothesis.
4) Research on the Thai seventh-grade students' ability to formulate scientific hypothesis.

II. REVIEW OF LITERATURE

1. Nature of Scientific Knowledge and Nature of Science (NOS)

The comprehension of the nature of science (NOS) and the characteristics of scientific knowledge recently have received considerable attention for learning and teaching of science (A.B.D.-El-Khalick & Lederman, 2000). Many times, nature of science and scientific knowledge are understood in the same meaning. However, Meichtry (1999) explained that the differences generally relate to the distinctions which are made between the terms "science" and "scientific knowledge". Nature of science attests to science as a human activity, a process used to investigate natural phenomena, a process used to add to an existing knowledge base, and a social enterprise. Meanwhile, scientific knowledge is a product of the human process of science and its social context.

1.1. Nature of Scientific Knowledge

The definition of scientific knowledge is tentative and dynamic. Cothum and Smith (1981) defined scientific knowledge as tentative and revisionary. Showalter (1974) defined that it is tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic and empirical. Additionally, Youngsoo Kim (2010) suggested the five aspects of nature of scientific knowledge which are shown in Table II-1.

Table II-1. Aspects of nature of scientific knowledge (Kim, 2010)

Aspects of Nature of Scientific Knowledge
1) Scientific knowledge is made up by a scientist.
2) Scientific knowledge is created from the valid grounds.
3) Scientific knowledge is incomplete.
4) Scientific knowledge can change over the time.
5) Scientific knowledge must be verifiable.

1.2. Nature of Science (NOS)

The concept of nature of science has changed throughout the development of science and is reflected in the ways the scientific and science education communities have defined (Flick & Lederman, 2004). Urhahne, Kremer, and Mayer (2011) explained that the concept of NOS is tentative and dynamic. It contains conceptions of scientific knowledge and knowing, values and beliefs incorporated in gaining scientific knowledge, as well as the influence of society, culture, and technology on science. However, many educators accepted that nature of science is the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992).

Flick and Lederman (2004) presented some agreeable components of NOS—are accessible to K-12 students— derived from an analysis of eight international sciences standard document as presented in Table II-2. Additionally, American Association for the Advancement of Science (1993) defined the nature of science consisted of three components as presented in Table II-3.

Table II-2. Aspects of nature of science (Flick & Lederman, 2004)

Aspects of Nature of Science
1. The Empirical Nature of Scientific Knowledge
2. Observation, inference, and theoretical entities in science
3. Scientific Theories and laws
4. The creative and Imaginative Nature of Scientific Knowledge
5. The Theory-laden Nature of Scientific Knowledge
6. The Social and Cultural Embeddedness of Scientific Knowledge
7. Myth of Scientific Method
8. The Tentative Nature of Scientific knowledge

Table II-3. Aspects of nature of science (AAAS, 1993)

Aspects of Nature of Science
1. Scientific worldview - the world is understandable, scientific ideas are subject to change, scientific knowledge is durable, and science cannot provide complete answers to all questions.
2. Scientific methods of inquiry - science demands evidence, science is a blend of logic and imagination, science explains and predicts, scientists try to identify and avoid bias, and science is not authoritarian.
3. Nature of the scientific enterprise - science is a complex social activity, science is organized into content disciplines and is conducted in various institutions, there are generally accepted ethical principles in the conduct of science, and scientists participate in public affairs both as specialists and as citizens.

1.3. Measuring the Concepts of NOS

Reviewing previous studies about nature of science have indicated that various instruments were conducted to measure the concepts of NOS from students, teachers, and educators. The examples of the instruments used to measure NOS views are presented in Table II-4.

1.4. Nature of Science in Thai Context

Nature of science is a critical component of scientific literacy, a goal of science education reform in Thailand and many countries (AAAS, 1993; IPST, 2013). To accept the Thailand education reform, the Ministry of Education launched the new Basic Education Core Curriculum B.E. 2545 (A.D. 2002) to accord with the National Education Act B.E. 2542. In the science learning area of the core curriculum, nature of science is firstly mentioned in the sub-strand 8: Nature of Science and Technology, the content is as follows:

> *The student should be able to use the scientific process and scientific mind in investigation, solve problems, know that most natural phenomena have a definite period of investigation, [and] understand that science, technology and environment are interrelated (IPST, 2013).*

Table II-4. The examples of the instruments used to measure NOS views

Instruments	Developer (s)	Structure	NOS topics
Test on Understanding Science (TOUS)	Cooley and Klopfer (1961)	60 four-alternative multiple-choice items	Understanding about the scientific enterprise, scientists, methods and aims of science
Nature of Science Scale (NOSS)	Kimbal (1968)	29 three-point Likert-type items	Tentative and dynamic nature of science assumptions, values of science and lack of a single "Scientific Method"
Nature of Scientific Knowledge Scale (NSKS)	Rubba and Anderson (1978)	48 five-levels Likert-type items	Six subscales: amoral, creative, developmental, parsimonious, testable, and unified
Modified NSKS	Meichtry (1992)	32 statements from NSKS	Creative, developmental, testable, and unified
View of Nature Of Science C (VNOS- C)	Lederman, Abd-ElKhalick, Bell, Swartz (2002)	10 open-ended questions	Philosophy of science based on Kuhnian (1970) views (Tentative, empirical, creative, subjective, social embeddedness, scientific theories, and laws
Student Understanding of Science and Scientific Inquiry Science (SUSSI)	Liang et al., (2008)	24 questions with 5 point Likert scale and 6 open-ended questions followed by the close ended question	Tentativeness, empirical basis, observations and inferences, creativity and imagination, social and cultural embeddedness, scientific theories and laws, multiple methods of scientific investigation

2. Scientific Inquiry

Scientific inquiry has been a perennial focus of science education for the past century. The National Science Education Standards (NRC, 1996) defined scientific inquiry as "the diverse way in which scientists study the nature world and propose explanations base on the evidence derived from their work". Moreover, scientific inquiry refers to the combination of general science process skills with traditional content, creativity, and critical thinking to develop scientific knowledge (Flick & Lederman, 2004). Too often, "scientific process", or "scientific method" are used to characterize scientific inquiry (Grandy & Duschl, 2007). To be clear, this study uses inquiry in the term of the "scientific method".

2.1. Science Processes

Scientific inquiry is the processes that the scientists use to generate the knowledge. The "processes" characterize the activities of scientists, the way to locate and gather information, explore, search, and discover the truths of nature. The science processes outcome is the intellectual skills required for scientific investigation attained by students as a result of learning of science. Wilke and Straits (2005) pointed that science process skills are the tools by which inquiry is conducted.

A process approach (SAPA) program launched by The Commission on Science Education of the American Association for the Advancement of Science (AAAS, 1971) emphasizes the laboratory method of instruction and learning of scientific processes by children. The goal of SAPA is students' mastery of scientific processes. In SAPA, the science processes are categorized into eight basic and five integrated processes (Table II-5). This twelve science processes are also included in the Thailand Science Curriculum.

Table II-5. SAPA's science processes of inquiry process (AAAS, 1971)

Level	Process	Details
Basic Processes	1) Observing	Using five senses to obtain information.
	2) Using space/time relationship	Describing spatial relationships and their change with time.
	3) Classifying	Imposing order on collections of objects or events.
	4) Using numbers	Identifying quantitative relationships in nature.
	5) Measuring	Measuring length, area, volume, weight, temperature, force, and speed.
	6) Communicating	Expressing ideas with oral and written words, diagrams, maps, graphs, mathematical equations, and various kinds of visual demonstrations.
	7) Predicting	Making specific forecasts of what a future observation will be.
	8) Inferring	An explanation of an observation.
Integrated Processes	1) Controlling variables	Studying the influence of changing variables, the factors, which influence one another.
	2) Interpreting data	Using data to make inferences, predictions and hypotheses, the statistical treatments given to such interpretations, and the study of probability.
	3) Formulating hypotheses	Making generalized statements of explanations.
	4) Defining operationally	Defining terms in the context of experience.
	5) Experimenting	Larger process of using basic and integrated processes.

2.2. Scientific Method

Scientific method can be split up into various component parts (Woolnough, 1985). This point concurs with Bell and Blair's (2003) which was argued that "There is no single prescribed set of procedures that all scientists follow when conducting investigations. Rather, scientists use a variety of methods and approaches when conducting research".

Karl Pearson's (1937) steps of scientific inquiry include many of the science processes. The steps are listed as below:

1. The problem is identified.
2. Pertinent observations to the problem are gathered.
3. A hypothesis based on the observations is developed and stated.
4. Testable predictions of other related observable phenomena are developed from the hypothesis.
5. The hypothesis is tested through observations.
6. As a result of empirical observations, the hypothesis is supported, rejected or modified.

Meanwhile, the middle school 1 science textbook for Thai students (standard science textbook) (2008) suggests that scientific method includes six steps:

1. Observing
2. Identifying the problem
3. Hypothesizing
4. Investigating, experimenting, and collecting data
5. Interpreting
6. Concluding

Youngsoo Kim (2010) developed the hypothesis-based model of scientific method (Table II-6) which emphasized on hypothesis, so this study used this model as a research framework.

Table II-6. The hypothesis-based model of inquiry process

Inquiry Process	Details
1) Recognition of inquiry problem	To be clear about the problem of inquiry.
2) Extraction of related variables	Extract the variables related to the inquiry problem.
3) Formulating hypothesis	Infer the answer to the inquiry problem.
4) Prediction from hypothesis	If the hypothesis is true, predict what will happen under certain experimental condition by using "If hypothesis = (true), then prediction" form.
5) Experimental design	Design the experiment by considering the variables control.
6) Interpretation of results and data	Compare prediction with experimental results.
7) Drawing conclusion	Consider the results that support or reject the hypothesis.

2.3. Scientific Method Terms

Youngsoo Kim (2011) pointed that in scientific method: prediction, conclusion, and assumption are easy to be confused with the hypothesis. Table II-7 shows the definition of assumption, prediction, and conclusion which is used as a framework for this study.

Table II-7. Definition of scientific method terms

Scientific Terminology	Definition
Assumption	An auxiliary hypothesis that is taken as true for the purposes of interpreting a particular test. It is a statement that does not object to judge right or wrong.
Prediction	It is inferring what will be happened or be observed in a certain experiment condition on the basis of the scientist's background knowledge.
Conclusion	The final process of the basic scientific method by which scientists examine the data from the experiment that will be judged whether accept or reject the hypothesis.

3. Scientific Hypothesis

Hypotheses are regarded as tentative answers or possible solutions to a question or problem (Wenham, 1993); it is a formal statement that presents the expected relationship between an independent and dependent variable (Creswell, 1994). Moreover, Youngsoo Kim (2010) suggested that hypothesis is the best tentative answer to the inquiry problem and a generalized statement based on valid grounds as shown in Figure II-1.

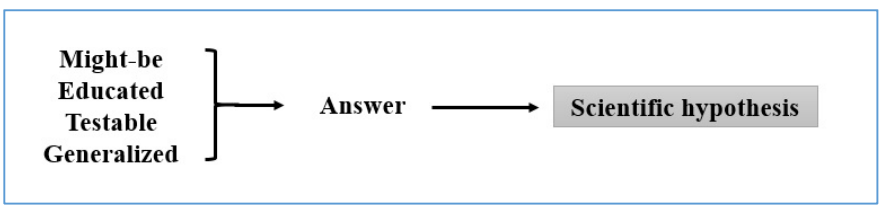

Figure II-1. The factors of hypothesis (Kim, 2010)

Many educators agree that hypothesis is an important factor of scientific inquiry because it provides a key where we have to follow to find the answers and develop new theories (Lawson, 2000; Oh, 2010). The formulating hypothesis is the one activity of central importance in any scientific investigation. To formulate the hypothesis, it always requires individual initiative and imagination. Generally, scientists prefer to generate a generalization hypothesis to describe an observed pattern in nature or phenomena. This sense is support by Strode (2015) who argued that “We often use generalizing hypotheses to summarize patterns we observe in nature, and we can refer to these types of hypotheses as immature laws (generalizing hypothesis). If the generalizations hold true over and over again, they become established laws of nature."

3.1. The Aspects of Scientific Hypothesis

Youngsoo Kim (2010) presented the six aspects of scientific hypothesis which is used as this research framework as below:

1. Scientific hypothesis is formulated from the valid grounds.
2. Scientific hypothesis is formulated from the relationship between independent and dependent variables.
3. Scientific hypothesis must be verified.
4. Scientific hypothesis is a testable statement.
5. Scientific hypothesis is incomplete.
6. Scientific hypothesis can be changed.

3.2. Ability to Formulate Scientific Hypothesis

Quinn and George (1975) suggested that a statement with acceptable hypothesis had to satisfy *at least one* of the following criteria:

1) It makes sense
2) It is empirically based
3) It is adequate
4) It is precise
5) It states a test

Based on these criteria, a Hypothesis Quality Scale (Table II-8) was constructed for the purpose of evaluating students' hypotheses.

Table II-8. Hypothesis quality scale (Quinn & George, 1975)

Criterion	Points given
No explanation, such as, a non-sense statement, a question, an observation, a single inference about a single concrete object.	0
Non-scientific explanation, such as, "…because it's magic" or "…because the man pushed a button."	1
Partial scientific explanation, such as, incomplete reference to variables, a negative explanation or analogy.	2
Scientific explanation relating at least two variables in general or non-specific terms.	3
Precise scientific explanation, a qualification and/or quantification of the variables.	4
Explicit statement of a test of a hypothesis. (An inference is made here that the child who states a test is also able to adequately and precisely hypothesize.)	5

Peter (1992) emphasized the students' ability to generate testable hypothesis, so he created a criterion for categorizing students' ability to generate a testable hypothesis (Table II-9).

Table II-9. Criteria for categorizing students' ability to generate a testable hypothesis (Peter, 1992)

Response
Mentions independent variable only
Mentions dependent variable only
Mentions (relevant) control variable (s)
Mentions (irrelevant) variable(s)
Both key variables stated and correctly related in terms of a causal link
Both variables merely state without linking them
Mentions an entirely different investigation

Youngsoo Kim (2010) suggested that a good hypothesis should be (1) might-be, (2) educated guess, (3) testable and (4) generalized. To evaluate the ability to formulate a scientific hypothesis, he constructed criteria listed of the ability to formulate a scientific hypothesis (Table II-10) which is used as a framework for this study.

According to a testable scientific hypothesis, this study defined it as a statement which consists of the empirical relationship among variables and the variables must be clear to measure, control or manipulate.

Table II-10. Criteria for evaluating the ability to formulate scientific hypothesis (Kim, 2010)

Evaluation Category	Details
Did you state the hypothesis as an answer to the inquiry question?	Present hypotheses as answers to inquiry questions.
	Present hypotheses as answers to other inquiry questions
	Restatement of the phenomenon or inquiry questions.
	Presenting other phenomena or inquiry problems
	I do not know
Was the relationship between the independent variable and the dependent variables correctly represented?	Present the relationship between one independent variable and one dependent variable.
	Present the relationship between multiple independent variables and one dependent variable.
	Present only one independent variable
	Present many independent variables only
Is the stated hypothesis verifiable?	Testable
	Untestable
Did you set a hypothesis based on valid grounds?	Present the valid grounds
	Present the unreasonable grounds
	Explanation of the hypothesis
	Restatement of hypothesis
	No evidence
Did you state the generalization hypothesis?	Yes
	No

3.3. Measuring the Awareness of and Ability to Formulate Scientific Hypothesis

In 2012, Haemin Yum developed the Ability to Formulate Scientific Hypothesis Questionnaire to investigate the Korean middle school students. The purpose of the questionnaire was to survey the students' awareness of nature of scientific knowledge, scientific method, scientific hypothesis and ability to formulate a scientific hypothesis. The question contents of the questionnaire were shown in Table II-11.

Table II-11. The question contents of the questionnaire (Yum, 2012)

Question contents		Details of investigation
1) Awareness of nature of scientific knowledge		Do students have a good understanding of the creation of scientific knowledge?
		Do students know that the scientific knowledge is created from the reasonable ground?
		Do students know that the scientific knowledge is incomplete?
		Do students know that the scientific knowledge can change over the time?
2) Awareness of scientific method terms	Awareness of scientific method terms (hypothesis,	Have students heard about the scientific method terms?
		Where did students hear about the scientific method terms?

	prediction, assumption, and conclusion)	How well do students know about the scientific method terms?
	Ability to distinguish hypothesis from other scientific method terms in a given inquiry situation	Can students distinguish hypothesis from the definitions of other scientific method terms?
		Can students distinguish hypothesis from other scientific method terms in a given inquiry situation?
	Can students order the correct scientific method from the scientific processes in a given situation?	
3) Awareness of scientific hypothesis		Do students know that scientific hypothesis is formulated from the valid grounds?
		Do students know that scientific hypothesis is formulated from the relationship between independent and dependent variables?
		Do students know that the scientific hypothesis must be verified?
		Do students know that scientific hypothesis is a testable statement?

	Do students know that scientific hypothesis is incomplete?
	Do students know that scientific hypothesis can be changed?
4) Ability to formulate scientific hypothesis	Can students formulate a scientific hypothesis as an answer of inquiry problem?
	Can students formulate a scientific hypothesis which presents the empirical relationship among variables?
	Can students formulate a testable hypothesis?
	Can students formulate a scientific hypothesis from a valid ground?
	Can students formulate a generalization hypothesis?

III. METHODOLOGY

1. Subjects

A total of 285 seventh-grade students who studied in a formal program, participated in the study voluntarily. In an attempt to ensure that the participants were reasonably representative of the diversity of students found in the population of Thailand, the subjects were selected from three schools located in Bangkok (capital city), Saraburi and Ubon Ratchathani. The three schools are characterized by a co-educational and public schools with similar average scores in for general science of the Ordinary National Educational Test (O-net).

Six classes from three schools—two classes per school— participated in the study. The 99 subjects (37 boys and 62 girls) were from school A located in Bangkok, the 97 subjects (38 boys and 59 girls) were from school B located in Saraburi and the 89 subjects (37 boys and 52 girls) were from school C located in Ubon Ratchathani. However, four cases were excluded because those questionnaires were missed or outliers, so only 281 seventh-grade students (108 boys and 173 girls) were counted in this study. The information about the schools of the subjects is shown in Table III-1.

Table III-1. The characteristics of the participating schools

School	Location	Average 2016 O-net Scores for General Science (%)	Number of Subjects (281)
School A	Bangkok (capital city)	56.60%	98 (36 boys and 62 girls)
School B	Saraburi	49.04%	95 (36 boys and 59 girls)
School C	Ubon Ratchathani	55.24%	88 (36 boys and 52 girls)

2. Research Instrument

Ability to Formulate Scientific Hypothesis Questionnaire developed by Haemin Yum (2012) was used as an instrument in this study. The questionnaire is composed of six parts: (1) Nature of Scientific Knowledge, (2) Scientific Method, (3) Scientific Method Terms, (4) Scientific Hypothesis, (5) Confusing Scientific Method Terms, and (6) Ability to Formulate Scientific Hypothesis. The questionnaire is short enough to be completed by subjects in 30 minutes. Table III-2 shows the overview of the questionnaire related to the research contents.

Because the original version of the questionnaire was designed for Korean Middle School students, all statements were in the Korean language. Careful translation as suggested by Harkness and Schoua-Glusberg (1998) was carried out. Firstly, the questionnaire was translated into English by a researcher and some contents were appropriately modified for Thai science curriculum and Thai Middle School students. Then a Korean science educator was asked to check the content validity. Lastly, the English version of the questionnaire was translated into the Thai language by a Thai researcher.

A preliminary test was conducted with 30 Thai Middle School students in order to determine whether they understood the items. The results of the preliminary test were used to revise and make it easier for students to understand the term of the questionnaire. After that, the content validity and appropriateness of the language of the second version questionnaire were checked by three science educators, any errors found were used to revise for the final version. The questionnaire is attached as Appendix.

Table III-2. The overview of questionnaire related to the research contents

Research Contents	Type of Questionnaire	Detail of Questionnaire	Contents Detail
Awareness of nature of scientific knowledge	Closed-ended	Three-point scale	Part 1: Nature of Scientific Knowledge
Awareness of scientific method	Closed-ended	Rank Ordering	Part 2: Scientific Method
		Check list	Part 3: Scientific Method Terms
		Three-point scale	Part 4: Scientific Hypothesis (item: 1,2,3, 10)
		Check list	Part 5: Confusing Scientific Method Terms
Awareness of scientific hypothesis	Closed-ended	Three-point scale	Part 4: Scientific Hypothesis (except item 1,2,3,10)
Ability to formulate scientific hypothesis	Open-ended	Direction: Please formulate a hypothesis from Kaew's question.	Part 6: Ability to Formulate Scientific Hypothesis
		Direction: From the question 1), please write the basic information (background, knowledge, experience etc.) that you used to formulate your hypothesis.	

3. Data Collection

The data collection was done in the second semester of 2016 academic year. A total of 285 seventh-grade students from three Thai public schools were asked to answer the Awareness of and Ability to Formulate Scientific Hypothesis Questionnaire (Thai version), which took about 30 minutes. In schools A and B, the data collection was implemented by the seventh-grade science teacher. Meanwhile, collecting data of the school C was implemented by the researcher. The data was collected from two classes in each school, during the science class or after school. After finishing, the science teachers from school A and B sent the questionnaires back to the researcher.

4. Data Analysis

The questionnaire consists of a close-ended form and open-ended form. According to a close-ended form which includes of three-point scales (agree, disagree, and uncertain), checklist and Rank order, the data were analyzed and counted to find the frequency of each item and calculated as a percentage. For the open-ended form which aimed to investigate the ability to formulate a scientific hypothesis, the data were analyzed by using the criteria for evaluating the ability to formulate scientific hypothesis suggested by Youngsoo Kim (2010). Firstly, the written responses were interpreted and classified whether it is represented to the answer of inquiry problem or not. Secondly, the written responses which presented the answer to the inquiry problem were analyzed in the other parts. Finally, analyzed data were counted to find the frequency of each item and calculated as a percentage. In order to ensure the accuracy of the output, the statistical test was performed by using SPSS software program. The overview of data analysis was shown in Table III-3.

Table III-3. The overview of data analysis

Research Contents	Type of Questionnaire	Contents	Theory for Analysis	Data Analysis
Awareness of nature of scientific knowledge	Closed-ended (Three-point scale)	Part 1: Nature of Scientific knowledge	The aspects of scientific knowledge suggested by Youngsoo Kim (2010)	Quantitative data 1. Count frequency 2. Calculate as %
Awareness of scientific method	Closed-ended (Rank Ordering)	Part 2: Scientific Method	A hypothesis-based model of scientific method suggested by Youngsoo Kim (2010)	
	Closed-ended (Check list)	Part 3: Scientific Method Terms	-	
	Closed-ended (Three-point scale)	Part 4: Scientific hypothesis (item: 1,2,3, 10)	Definition of scientific method terms (Table II-7)	
	Closed-ended (Check list)	Part 5: Confusing scientific method terms		
Awareness of scientific hypothesis	Closed-ended (Check list)	Part 4: Scientific hypothesis (except item 1,2,3,10)	The aspects of scientific hypothesis suggested by Youngsoo Kim (2010)	
Ability to formulate scientific hypothesis	Open-ended	Part: 6 Ability to formulate scientific hypothesis	Criteria for evaluating the ability to formulate scientific hypothesis suggested by Youngsoo Kim (2010)	Qualitative Data 1. Content Analysis 2. Count frequency 3. Calculate as %

IV. RESULTS AND DISCUSSIONS

The study used the Awareness of and Ability to Formulate Scientific Hypothesis Questionnaire (Thai version) to reveal Thai Seventh-grade students' awareness of and ability to formulate scientific hypothesis, by surveying the students about (1) awareness of nature of scientific knowledge, (2) awareness of scientific method, (3) awareness of scientific hypothesis, and (4) ability to formulate scientific hypothesis. The data were collected in the second semester 2016 academic year. A total of 285 of Thai seventh-grade students participated in this study, but the effective participant size was only 281 (98.6%) and 4 (1.4%) were excluded because the answers were missing or outliers. The findings were as follows:

1. Awareness of Nature of Scientific Knowledge

The results of Thai seventh-grade students' awareness of nature of scientific knowledge were categorized into four parts as follows:

1.1. Thai Seventh-grade Students' Awareness of Scientific Knowledge: Scientific Knowledge Is Made up by Scientist

According to Table IV-1, more than three-quarters (78.6%) of Thai seventh-grade students believed that scientific knowledge already exists in nature, discovered by scientists. Most of them (41.3%) also believed that scientific knowledge is an explanation of a natural phenomenon which is made by scientists. Nearly half of the students (41.3%) thought that scientific knowledge is an explanation of a natural phenomenon which is made by scientists. Meanwhile, for the statement "Scientific knowledge is made by scientists", the students chose

"Agree" (39.1%) similarly to "Disagree" (39.5%). Therefore, the survey results indicated that Thai seventh-grade students understood that scientific knowledge was discovered by scientists rather than being made by scientists.

Table IV-1. Frequencies and percentages for Thai seventh-grade students' awareness of scientific knowledge: scientific knowledge is made up by scientist

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
Scientific knowledge already exists in nature, discovered by scientists. (R*)	221 (78.6%)	28 (10.0%)	28 (10.0%)	4 (1.4%)	281 (100.0%)
Scientific knowledge is made by scientists.	110 (39.1%)	111 (39.5%)	52 (18.5%)	8 (2.8%)	281 (100.0%)
In order to explain natural phenomena, scientist discovers scientific knowledge that exists in nature. (R*)	244 (86.8%)	11 (3.9%)	26 (9.3%)	0 (0.0%)	281 (100.0%)
Scientific knowledge is an explanation of natural phenomenon which is made by scientists.	116 (41.3%)	95 (33.8%)	68 (24.2%)	2 (0.7%)	281 (100.0%)

* R= Reverse question

1.2. Thai Seventh-Grade Students' Awareness of Scientific Knowledge: Scientific Knowledge Is Created from the Valid Grounds

According to Table IV-2, the majority of the students agreed with the statements "When a scientist explains a natural phenomenon, the explanation has to be supported by evidence" (96.4%), and "A scientist explains based on his or her

knowledge when explaining a natural phenomenon" (56.2%). Additionally, for the reverse questions: "When a scientist explains a natural phenomenon, even if there is no supporting evidence, it is ok" and "When a scientist explains a natural phenomenon, that is plausible without any basis for it, we can accept as a scientific knowledge", most of the students answered "Disagree" (87.9% and 51.2% respectively). In sum, the survey results indicated that Thai seventh-grade students have understood that scientist created the scientific knowledge from the valid grounds to explain a natural phenomenon.

Table IV-2. Frequencies and percentages for awareness of scientific knowledge: scientific knowledge is created from the valid grounds

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
When a scientist explains a natural phenomenon, even if there is no supporting evidence, it is ok. (R*)	9 (3.2%)	247 (87.9%)	23 (8.2%)	2 (0.7%)	281 (100.0%)
When a scientist explains a natural phenomenon, the explanation has to be supported by evidence.	271 (96.4%)	4 (1.4%)	6 (2.1%)	0 (0.0%)	281 (100.0%)
When a scientist explains a natural phenomenon, that is plausible without any basis for it, we can accept as a scientific knowledge. (R*)	65 (23.1%)	144 (51.2%)	72 (25.6%)	0 (0.0%)	281 (100.0%)
A scientist explains based on his or her knowledge when explaining a natural phenomenon.	158 (56.2%)	64 (22.8%)	56 (19.9%)	3 (1.1%)	281 (100.0%)

* R= Reverse question

1.3. Thai Seventh-Grade Students' Awareness of Scientific Knowledge: Scientific Knowledge Is Incomplete

The results of the Thai seventh-grade students' awareness of scientific knowledge: scientific knowledge is incomplete were shown in Table IV-3.

Table IV-3 Frequencies and percentages for awareness of scientific knowledge: scientific knowledge is incomplete

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
Scientific knowledge fully explains the natural world. (R*)	86 (30.6%)	95 (33.8%)	95 (33.8%)	5 (1.8%)	281 (100.0%)
Scientific knowledge cannot fully explain the natural world.	161 (57.3%)	50 (17.8%)	66 (23.5%)	4 (1.4%)	281 (100.0%)
Scientific knowledge is obtained through scientific method, so there can be no errors. (R*)	20 (7.1%)	187 (66.5%)	71 (25.3%)	3 (1.1%)	281 (100.0%)
Scientific knowledge may be incomplete because of his or her errors in conducting research.	199 (70.8%)	20 (7.1%)	60 (21.4%)	2 (0.7%)	281 (100.0%)

* R= Reverse question

Table IV-3 indicated that Thai seventh-grade students answered "Disagree" (33.8%) equally to "Uncertain" (33.8%) for the statement "Scientific knowledge fully explains the natural world". More than half of the students (57.3%) indicated that scientific knowledge cannot fully explain the natural world. Moreover, three-fourth of the students (70.8%) knew that scientific knowledge may be incomplete

because of his or her errors in conducting research. The students who disagreed with the idea that scientific knowledge is obtained through the scientific method, so there can be no errors, were 66.5%.

Since a number of the students who answered “Disagree” and “Uncertain” with the idea that scientific knowledge fully explains the natural world were equal, it means that they were confused with this statement. Nevertheless, when comparing with the other statements, the findings showed that the majority of the students had correct understanding for all of the others. Hence, most of the students are aware that scientific knowledge cannot fully explain the natural world and it may be incomplete.

1.4. Thai Seventh-Grade Students' Awareness of Scientific Knowledge: Scientific Knowledge Can Be Changed

According to Table IV-4, about 70% of Thai seventh-grade students disagreed with “Scientific knowledge is obtained through the scientific method, so even if time goes by, it won’t change” statement. More than half of the students (68.7%) disagreed with the idea that scientific knowledge has been achieved through discussion and reviewed by a group of scientists, so it does not change over time. Moreover, for the idea that scientific knowledge looks unchangeable, but it is changeable was supported by (86.5%). Nearly all of the students (93.2%) knew that scientific knowledge can change as new experimental evidence accumulates. Therefore, the survey results indicated Thai seventh-grade students realized that scientific knowledge is changeable when the new experimental evidence accumulates.

Table IV-4. Frequencies and percentages for scientific knowledge: scientific knowledge can be changed

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
Scientific knowledge is obtained through the scientific method, so even if time goes by, it won't change. (R*)	29 (10.3%)	214 (76.2%)	35 (12.5%)	3 (1.1%)	281 (100.0%)
Scientific knowledge looks unchangeable, but it is changeable.	243 (86.5%)	11 (3.9%)	26 (9.3%)	1 (0.4%)	281 (100.0%)
Scientific knowledge has been achieved through discussion and reviewed by a group of scientists, so it does not change over time. (R*)	34 (12.1%)	193 (68.7%)	51 (18.1%)	3 (1.1%)	281 (100.0%)
Scientific knowledge can change as new experimental evidence accumulates.	262 (93.2%)	7 (2.5%)	7 (2.5%)	5 (1.8%)	281 (100.0%)

* R= Reverse question

The survey results of Thai seventh-grade students' awareness of nature of scientific knowledge indicated that Thai seventh-grade students understood that scientific knowledge is created from valid grounds, incomplete and can change over the time. The results are consistent with Wongdontri (2013), and Ladachart (2012). However, the results are different from Lederman and O'Mally (1990), and Mahalee (2010), which reported the students misunderstanding in scientific knowledge is subject to change.

As the results of Thai seventh-grade students believed that scientific knowledge was discovered by scientists rather than being made by sciences, are similar to Yom's (2012) studied. The misunderstanding of this concept might occur because students in Thailand always hear or experience with the speech or headline "Scientist discovered …" from the news, newspaper, magazine, etc. The point concurred with Balfakin (1999) who argued that cultural background influenced student's views about the nature of science and learning process could be directly elicited by the introspections of their own learning experiences.

2. Awareness of Scientific Method

The survey results of Thai seventh-grade students' awareness of scientific method were categorized into two parts as follows: (2.1) perception of scientific method terms, and (2.2) ability to distinguish hypothesis from other scientific method terms. The results are as follows:

2.1. Perception of Scientific Method Terms

This part surveyed the Thai seventh-grade students' perception of scientific method terms including 'hypothesis', 'assumption', 'prediction', and 'conclusion'. The survey results are as follows:

2.1.1. Perception of Scientific Method Terms

The survey results of Thai seventh-grade students' perception of scientific method term were from the question "Have you ever heard about the following scientific terminologies?" The results indicated that nearly all of Thai seventh grade students have heard about 'hypothesis' (96.1%), 'prediction' (90.7%) and 'conclusion' (95.7%). However, about half of the students (49.8%) have heard about 'assumption' (see Table IV-5).

Table IV-5. Frequencies and Percentages for Thai seventh-grade students' perception of scientific method terms

Respond type	Assumption (%)	Hypothesis (%)	Prediction (%)	Conclusion (%)
Yes	140 (49.8%)	270 (96.1%)	255 (90.7%)	269 (95.7%)
No	139 (49.5%)	11 (3.9%)	26 (9.3%)	12 (4.3%)
No answer	2 (0.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	281 (100%)	281 (100%)	281 (100%)	281 (100%)

2.1.2. Sources of Scientific Method Terms' Perception

The survey results about sources of scientific method terms were from the question "If you have heard about the scientific terminologies, where did you hear about it?" The result indicated that Thai seventh-grade students have heard 'assumption' from science class (34.2%), followed by school teachers (25.4%), books (20.2%), mass communication (15.8%), and friends (4.4%). The majority of the students have heard 'hypothesis' from science class (40.0%), followed by school teachers (32.0%), books (10.2%), mass communication (8.9%), friends (8.0%), and cram schools (0.9%). For 'prediction', they have heard from science class (28.3%), mass communication (23.9%), school teachers (22.3%), books (17.0%), friends (7.7%), and cram schools (0.8%). Lastly, the majority of the students have heard 'Conclusion' from school class (32.6%), school teachers (32.6%), mass communication (13.5%), books (9.6%), and friends (8.7%) (see Table IV-6).

The majority of Thai seventh-grade students have heard about assumption, hypothesis, prediction, and conclusion from the science class. Moreover, they also have heard from school teachers, books, magazine, and mass communication such

as TV, radio, friend, and cram schools. Therefore, the survey results indicated that Thai seventh-grade students have heard about scientific method terms from various sources.

Table IV-6. Frequencies and percentages for source of scientific method terms' perception (Student can choose more than one)

Sources	Assumption (%)	Hypothesis (%)	Prediction (%)	Conclusion (%)
Science class	39 (34.2%)	90 (40.0%)	70 (28.3%)	82 (35.7%)
School teacher (s)	29 (25.4%)	72 (32.0%)	55 (22.3%)	75 (32.6%)
Friend (s)	5 (4.4%)	18 (8.0%)	19 (7.7%)	20 (8.7%)
Books (books, magazine, journal, etc.)	23 (20.2%)	23 (10.2%)	42 (17.0%)	22 (9.6%)
Mass communication (TV, radio, newspaper etc.)	18 (15.8%)	20 (8.9%)	59 (23.9%)	31 (13.5%)
Others (Cram schools)	0 (0.00%)	2 (0.9%)	2 (0.8%)	0 (0.0%)
Total	114 (100.0%)	225 (100.0%)	(247 100.0%)	230 (100.0%)

2.1.3 Students' Understanding of Scientific Method Terms

The survey results of Thai seventh-grade students about students' understanding of scientific method term were from the question "How well do you understand each of following scientific terminology?" The results indicated that for the term 'assumption', most of Thai seventh-grade students answered: "I don't understand" (41.3%), followed by "I understand it a little" (39.5%), and "I

understand" (18.5%). For 'hypothesis', most of the students answered: "I understand" (78.6%), followed by "I understand it a little" (17.4%), and "I don't understand" (3.6%). Additionally, for 'prediction', most of the students answered: "I understand" (64.1%), followed by "I understand it a little" (28.8%), and "I don't understand" (6.8%). Finally, for 'conclusion', most of the students understood (69.4%), followed by understood it a little (24.2%), and didn't understand (6.0%) (see Table IV-7).

Therefore, the survey results indicated that most of Thai seventh-grade students thought that they understood about the terms of 'hypothesis', 'prediction', and 'conclusion' while they did not understand about 'assumption'. These results were strongly supported by the students' perception of scientific method terms that half of them have not heard about assumption (Table IV-5). Moreover, after analyzing Thai standard science textbooks, from elementary school books to middle school textbooks, the findings showed that the term 'assumption' did not present in any science textbooks. Hence, the students might not familiar with this term.

Table IV-7. Frequencies and percentages for students' understanding of scientific method terms

Level of Understanding	Assumption (%)	Hypothesis (%)	Prediction (%)	Conclusion (%)
I understand	52 (18.5%)	221 (78.6%)	180 (64.1%)	195 (69.4%)
I understand it a little	111 (39.5%)	49 (17.4%)	81 (28.8%)	68 (24.2%)
I don't understand	116 (41.3%)	10 (3.6%)	19 (6.8%)	17 (6.0%)
No answer	2 (0.7%)	1 (0.4%)	1 (0.4%)	1 (0.4%)

Total	281 (100.0%)	281 (100.0%)	281 (100.0%)	281 (100.0%)

2.2. Ability to Distinguish Hypothesis from Other Scientific Method Terms

This part surveyed Thai seventh-grade students' ability to distinguish hypothesis from other scientific method terms (assumption, prediction, and conclusion). The results are as follows:

2.2.1. Ability to Distinguish Hypothesis from Other Scientific Method Terms in a Giving Definition

The survey results of this part were from the Part 4 of the questionnaire (items 1, 2, 3, and 10). The results indicated that the majority of the students (76.5%) agreed with the statement which presents the definition of 'assumption' and 17.1% answered the question with "Disagree" while less than 10% answered "Uncertain". For the statements which presented the definition of 'prediction', three-quarters of the students (73.7%) answered: "Agree", followed by "Disagree" (13.0%), and "Uncertain" (12.8%). For the definition of 'conclusion', almost half of the students (45.2%) also answered: "Agree", followed by "Disagree" (42.3%), and "Uncertain" (12.1%) (see Table IV-8). Therefore, we can conclude that most of Thai seventh-grade students agreed with every item, it indicated that they could not distinguish 'hypothesis' from other scientific method terms in a giving definition, especially the difference between 'prediction' and 'hypothesis'.

Table IV-8. Frequencies and percentages for ability to distinguish hypothesis from other scientific method terms in a giving definition

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
Hypothesis vs Assumption					
The hypothesis is a temporary answer to research problem, so it does not need to be judged right or wrong. (R*) (Definition of Assumption)	215 (76.5%)	48 (17.1%)	17 (6.0%)	1 (0.4%)	281 (100.0%)
Hypothesis vs Prediction					
The hypothesis is inferring about what will happen or be observed in a certain experimental condition on the basis of scientist background knowledge. (R*) (Definition of Prediction)	218 (77.6%)	36 (12.8%)	26 (9.3%)	1 (0.4%)	281 (100.0%)
The hypothesis is a statement about what will happen or be observed in a certain experimental condition. (R*) (Definition of Prediction)	196 (69.8%	37 (13.2%)	46 (16.4%)	2 (0.7%)	281 (100.0%)
Average	73.7%	13.0%	12.8%)	0.5%	100.0%
Hypothesis vs Conclusion					

The hypothesis is the results of the experiment that will be judged whether accept or reject the temporary answer (R*) (Definition of Conclusion)	127 (45.2%)	119 (42.3%)	34 (12.1%)	1 (0.4%)	281 (100.0%)

* R= Reverse question

2.2.2. Ability to Distinguish Hypothesis from Other Scientific Method Terms in a Giving Scientific Situation

In this part, the students were asked to categorize the specific statements into the terms of 'hypothesis', 'assumption', 'prediction', 'conclusion', or 'inquiry question'. According to Table IV-9, for the statement which presented the situation of 'assumption', most of Thai seventh-grade students thought that it was "assumption" (48.8%), followed by 'conclusion' (14.6%), "I don't know" (11.7%), 'prediction' (10.7%), 'inquiry question' (6.4%), and 'hypothesis' (6.0%). For the 'hypothesis' situation statements, nearly half of the students (47.7%) answered 'hypothesis' while 15.0% answered 'conclusion', 14.7% answered 'prediction', 9.2% answered 'assumption', 6.3% answered 'inquiry question', and 6.2% answered 'I don't know'. For the 'prediction' situation statements, one-quarters of the students (28.9%) answered 'hypothesis', followed by 23.1% answered 'prediction', 17.9% answered 'conclusion', 16.1% answered 'assumption', 9.3% who answered 'I don't know', and 3.4% who answered 'inquiry question'. Lastly, for the 'conclusion' situation statements, more than half of the students (58.5%) answered 'conclusion' followed by 'I don't know' (10.4%), 'assumption' (9.5%), 'hypothesis' (8.7%), 'prediction' (6.2%) and 'inquiry question' (4.6%).

The results indicated that most of Thai seventh-grade students could correctly identify 'assumption', 'hypothesis', and 'conclusion', but they could not distinguish 'prediction' from 'hypothesis' in a giving situation. Hence, Thai seventh-grade students were confused 'prediction' with 'hypothesis'.

Table IV-9. Frequencies and percentages for ability to distinguish hypothesis from other scientific method terms in a giving scientific situation

Questions	Answer (%)							
	Hypothesis	Assumption	Conclusion	Prediction	Inquiry Question	I don't know	No Answer	Total
				Assumption				
"chickens in his farm were fed only by human"	17 (6.0%)	137 (48.8%)	41 (14.6%)	30 (10.7%)	18 (6.4%)	33 (11.7%)	5 (1.8%)	281 (100.0%)
				Hypothesis				
"Because I had fed brown rice to chickens, symptoms were improved."	131 (46.6%)	27 (9.6%)	57 (20.3%)	34 (12.1%)	16 (5.7%)	14 (5.0%)	2 (0.7%)	281 (100.0%)
"Gazelles jump high because they want to keep their calves safe from the cheetahs"	172 (61.2%)	16 (5.7%)	31 (11.0%)	34 (12.1%)	14 (5.0%)	12 (4.3%)	2 (0.7%)	281 (100.0%)
"high jumping of gazelles is for showing the ability and power to the cheetahs"	100 (35.6%	35 (12.5%)	38 (13.5%)	56 (19.9%)	23 (8.2%)	26 (9.3%)	3 (1.1%)	281 (100.0%)
Average	47.7%	9.2%	15.0%	14.7%	6.3%	6.2%	0.8%	100%

Questions	Answer (%)							
	Hypothesis	Assumption	Conclusion	Prediction	Inquiry Question	I don't Know	No Answer	Total
Prediction								
"during the same period, chickens that are fed only polished rice will be sick, while chickens that are fed only brown rice will be healthy."	89 (31.7%)	49 (17.4%)	50 (17.8%)	61 (21.7%)	7 (2.5%)	21 (7.5%)	4 (1.4%)	281 (100.0%)
"when cheetahs appear, female gazelles which have calves will jump higher than female gazelles which don't have calves".	90 (32.0%)	44 (15.7%)	40 (14.2%)	80 (28.5%)	3 (1.1%)	20 (7.1%)	4 (1.4%)	281 (100.0%)
"low jumping gazelles will be attacked more than high jumping gazelles".	65 (23.1%)	43 (15.3%)	61 (21.7%)	54 (19.2%)	19 (6.8%)	37 (13.2%)	2 (0.7%)	281 (100.0%)
Average	28.9%	16.1%	17.9%	23.1%	3.4%	9.3%	1.2%	100.0%

Questions	Answer (%)							
	Hypothesis	Assumption	Conclusion	Prediction	Inquiry Question	I don't Know	No Answer	Total
				Conclusion				
"brown rice contains many nutrients which alleviate or prevent the symptoms."	12 (4.3%)	18 (6.4%)	211 (75.1%)	10 (3.6%)	7 (2.5%)	18 (6.4%)	5 (1.8%)	281 (100.0%)
"when cheetahs appeared, there was no difference whether female gazelles have calves or not".	46 (16.4%)	56 (19.9%)	89 (31.7%)	28 (10.0%)	22 (7.8%)	33 (11.7%)	7 (2.5%)	281 (100.0%)
"because the gazelles want to show their ability and power to cheetahs who want to attack them, so they always show the high jumping behavior when cheetahs appear."	15 (5.3%)	6 (2.1%)	193 (68.7%)	14 (5.0%)	10 (3.6%)	37 (13.2%)	6 (2.1%)	281 (100.0%)
Average	8.7%	9.5%	58.5%	6.2%	4.6%	10.4%	2.1%	100.0%

‘Hypothesis’ and ‘prediction’ are difficult to distinguish. Eastwell (2010) suggested that a hypothesis is a proposed explanation, whereas a prediction is the expected result of a test that is derived, by deduction, from a hypothesis. This argument is similar to the result of this study that Thai-seventh grade students could not distinguish ‘hypothesis’ from ‘prediction’ in many cases. Moreover, Yum (2012) and Eom (2012) reported that Korean students also could not distinguish hypothesis from prediction. For more supports of the results, many educators reported that not only students but also curriculum materials, teachers, and science education researchers themselves were often confused by hypothesis and prediction (Kim, 2010; Eastwell, 2010; Strode, 2015).

The possible reason why the majority of Thai seventh-grade students have been confused about ‘hypothesis’ and ‘prediction’ can be explained by (1) most of the students have heard ‘prediction’ from mass communication which is a part of their daily life so they might feel familiar with it more than ‘hypothesis’, (2) the content about the difference between ‘hypothesis’ and ‘prediction’ does not present in any Thai standard science textbooks, this means science curriculum does not place importance on both terms, and (3) In Thailand, science teaching methods are demonstrated by the hypothetico-deductive model which students have to use the form “if…, then…” logical linkage where the “if” phase is actually an experimental method, and the “then” phase is a specific prediction. This logical statement is always used to formulate the hypothesis for guiding the experimental test in the science class.

2.3. Awareness of Scientific Method

The investigation results of Thai seventh-grade students' awareness of scientific method, by asking the students to correctly order the steps of the scientific method in a giving scientific process, were shown in Table IV-10, IV-11, and IV-12. This part is the results of the questionnaire Part 2: scientific method.

Table IV-10. Frequencies and percentages for Thai seventh-grade students' order the steps of the scientific method

Answer	Number of students (%)
Correct sequence	12 (4.3%)
Incorrect sequence	226 (94.7%)
No answer	3 (1.1%)
Total	281

According to Table IV-10, only 4.3% of Thai seventh-grade students correctly sequenced the steps of scientific method while most of the students (94.7%) incorrectly sequenced the steps of the scientific method. Therefore, the results indicated that most of Thai seventh-grade students could not order correctly the steps of the scientific method.

Table IV-11. Frequencies and percentages for Thai seventh-grade students' awareness of the first step of scientific method

Answer	Number of students (%)
Start form scientific question	206 (73.3%)
Start from other steps	72 (25.6%)
No answer	3 (1.1%)
Total	281

Table IV-11 showed that 73.3% of the students ordered “Asking question” as the first step of scientific method while one-fourth of the students (25.6%) chose other steps. Thus, Thai seventh-grade students were aware that asking the question is the first step of the scientific method.

Regarding the 206 subjects who were aware that the first step of the scientific method is asking a question were analyzed in the awareness of the second step of scientific method part (Table IV-12).

Table IV-12. Frequencies and percentages for Thai seventh-grade students' awareness of the second step of scientific method

Answer	Number of students (%)
Asking question→ Variable extraction	22 (10.7%)
Asking question → Formulating hypothesis	19 (9.2%)
Scientific question→ Prediction	114 (55.3%)
Asking question → Experiment	14 (6.8%)
Asking question → Conclusion	1 (0.5%)
Total	206

Table IV-12 indicated that more than half of Thai seventh-grade students (55.3%) thought that ‘prediction’ is the second step of scientific method while only 10.7% ordered ‘variable extraction’. Moreover, 9.2% of the students chose ‘formulating hypothesis’, follow by ‘experiment’ (6.8%) and ‘conclusion’ (0.5%).

According to the hypothesis-based model of inquiry method (Kim, 2010), it explained that scientific method consisted of seven steps: 1) Recognition of inquiry problem, 2) Extraction of related variables, 3) Formulating hypothesis, 4) Prediction from hypothesis, 5) Experimental design, 6) Interpretation of result and data, and 7) Drawing conclusion. Based on the

model, it was necessary to extract the variables related to inquiry problem and use the extracted variables to formulate a hypothesis. However, Thai seventh-grade students thought that the first step of scientific method was "Asking question" and the second step was "Prediction" not "Variable extraction" The findings strongly support that Thai seventh-grade students confused 'hypothesis' with 'prediction' (Table IV-9). The misconception in this case, maybe happened because the students feel familiar with both of 'hypothesis' and 'prediction'. Moreover, the Middle School 1 science textbook (standard science textbook) suggests that the scientific method includes of six steps: (1) Observing, (2) Identifying the problem, (3) Hypothesizing, (4) Investigating, experimenting, and collecting data, (5) Interpreting, and (6) Concluding (IPST, 2013). For the hypothesizing process, the book only explains about the meaning, nature, the importance of hypothesis and shows a few examples of the hypothesis. However, the explanation about the extracted variables is presented in the investigating, experimenting, and collecting data process. Indeed, the book explains only about controlled variables and changed variables which lead to the performance of experiments. In other words, the book explains extracted variable after hypothesizing process so many students thought that the variable extraction process comes after formulating a hypothesis.

3. Awareness of Scientific Hypothesis

The survey results of Thai seventh-grade students' awareness of scientific hypothesis, which was from Part 4 of the questionnaire: scientific hypothesis, were classified into six parts as follows:

3.1 Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Is Formulated from the Valid Grounds

The survey results of Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is formulated from the valid grounds were shown in Table IV-13.

Table IV-13. Frequencies and percentages for Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is created from the valid grounds

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
The scientist formulates a hypothesis of the research problem from his or her previous knowledge or experience.	207 (73.7%)	24 (8.5%)	44 (15.7%)	6 (2.1%)	281 (100.0%)
When a scientist formulates hypothesis of the research problem, he or she can make it plausible even if it is not based on the previous knowledge. (R*)	103 (36.7%)	116 (41.3%)	59 (21.0%)	3 (1.1%)	281 (100.0%)

* R= Reverse question

According to Table IV-13, in the written responses, about 70% of Thai seventh-grade students thought that the scientist formulates a hypothesis of the research problem from his or her previous knowledge or experience while 15.7% and 8.5% were uncertain and disagreed respectively. Moreover, nearly half of the students (41.3%) disagreed with the idea that when a scientist formulates hypothesis of the research problem, he or she can make it plausible even if it is not based on the previous knowledge, follow by 36.7% and 21.0% of the

students who agreed and were uncertain respectively. Hence, most of Thai seventh-grade students were aware that scientific hypothesis is formulated from the valid grounds.

3.2. Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Is Formulated from the Relationship between the Independent and the Dependent Variables

The survey results of Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is formulated the relationship between independent and dependent variables were shown in Table IV-14.

Table IV-14. Frequencies and Percentages for the Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is formulated the relationship between two variables

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
The hypothesis is expressed by indicating the relationship between certain natural phenomena and the factors influencing the natural phenomena.	90 (32.0%)	108 (38.4%)	80 (28.5%)	3 (1.1%)	281 (100.0%)
The hypothesis is expressed by indicating the relationship between the factors that affect certain natural phenomena and the natural phenomena that are affected.	118 (42.0%)	63 (22.4%)	96 (34.2%)	4 (1.4%)	281 (100.0%)

Table IV-14 reported that for the statement "The hypothesis is expressed by indicating the relationship between certain natural phenomena and the factors influencing the natural phenomena", it was found that about one-third of Thai seventh-grade students (38.4%) answered, "Disagree" while only 32% answered "Agree" and 28.5% answered "Uncertain". For the statement "The hypothesis is expressed by indicating the relationship between the factors that affect certain natural phenomena and the natural phenomena that are affected", nearly half of the students (42.0%) agreed, followed by 34.2% and 22.4% of the students who were uncertain and disagreed respectively. In fact, a student who has correctly understood this aspect must answer "Agree" on both items. Therefore, the results indicated that Thai seventh-grade students did not understand clearly with the idea that scientific hypothesis is formulated from the relationship between two variables.

Consistent with the previous results, most of Thai seventh-grade students were unaware that the second step is 'variable extraction' from the inquiry question (Table IV-12). This means that many Thai seventh-grade students were not only unaware of the second step of the scientific method, but also were confused with the idea that scientific hypothesis is formulated from the relationship between independent and dependent variables. This might be because the science curriculum and teachers do not pay attention to the extraction variable process.

3.3. Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Must Be Verified

Thai seventh-grade students were aware that scientific hypothesis must be verified through the scientific way (see Table IV-15). Firstly, more than three-quarters of the students (76.9%) agreed with the idea that the hypothesis must be verified in a scientific way, even though it is made by the scientist", followed by uncertain (7.5%), and disagreed (14.2%). For the reverse statement "When the scientists formulate the hypothesis, they think that it is the best answer to the research problem, so it does not need any verification", most of the students disagreed (76.9%), followed by agreed (14.2%), and uncertain (8.2%).

Table IV-15. Frequencies and percentages for Thai seventh-grade students' awareness of scientific hypothesis: hypothesis must be verified

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	total
The hypothesis must be verified in a scientific way, even though it is made by the scientist.	216 (76.9%)	21 (7.5%)	40 (14.2%)	4 (1.4%)	281 (100.0%)
When the scientists formulate the hypothesis, they think that it is the best answer to the research problem, so it does not need any verification. (R*)	40 (14.2%)	216 (76.9%)	23 (8.2%)	2 (0.7%)	281 (100.0%)

* R= Reverse question

3.4. Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Is a Testable Statement

The survey results of Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is a testable statement were showed in Table IV-16.

Table IV-16 Frequencies and percentages for Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is a testable statement

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
The hypothesis must be testable through experimentation.	227 (80.8%)	32 (11.4%)	17 (6.0%)	5 (1.8%)	281 (100.0%)
The hypothesis must be judged whether it is right or wrong through experiments.	233 (82.9%)	22 (7.8%)	20 (7.1%)	6 (2.1%)	281 (100.0%)

The Table IV-16 indicated that Thai seventh-grade students who agreed with the hypothesis must be testable through experimentation and it must be judged whether it is right or wrong through experiments were 80.8%, while about 10% and less than 10% of the students disagreed and were uncertain respectively. For the statement "The hypothesis must be judged right and wrong through experiments", most of the students also agreed with 82.9% while a few of students answered, "Disagree" (7.8%) and "Uncertain" (7.1%). Therefore, the results indicated that Thai seventh-grade students knew that scientific hypothesis is a testable statement and must be judged right or wrong through experiments.

3.5. Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Is Incomplete

The survey results of Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is incomplete were showed in Table IV-17.

Table IV-17. Frequencies and percentages for Thai seventh-grade students' awareness of scientific hypothesis: hypothesis is incomplete

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
The hypothesis is made by scientist is always right. (R*)	21 (7.5%)	227 (80.8%)	24 (8.5%)	9 (3.2%)	281 (100.0%)
The hypothesis is made by scientist may not be true.	253 (90.0%)	17 (6.0%)	9 (3.2%)	2 (0.7%)	281 (100.0%)

* R= Reverse question

According to Table IV-17, a huge number of students (80.8%) disagreed with a reverse statement "The hypothesis which made by a scientist is always right", 24 students (8.5%) answered "Uncertain" and 21 students (7.5%) answered "agree". Moreover, for the idea that the hypothesis made by a scientist may not be true, nearly all of the students (90%) answered "Agree" while only 6.0% answered "Disagree", and 3.2% answered "Uncertain". To sum up, the results indicated that Thai seventh-grade students realized that scientific hypothesis is incomplete.

3.6. Thai Seventh-Grade Students' Awareness of Scientific Hypothesis: Scientific Hypothesis Can Be Changed

The survey results of Thai seventh-grade students' awareness of scientific hypothesis: hypothesis can be changed were showed in Table IV-18.

Table IV-18. Frequencies and percentages for Thai seventh-grade students' awareness of scientific hypothesis: hypothesis can be changed

Questions	Answer (%)				
	Agree	Disagree	Uncertain	No answer	Total
The hypothesis is a temporary answer to the research problem made by scientist.	191 (68.2%)	46 (16.4%)	43 (15.4%)	0 (0.0%)	281 (100.0%)
The hypothesis is the final answer to the research problem which scientist got from the experiment. (R*)	61 (21.7%)	187 (66.5%)	31 (11.0%)	2 (0.7%)	281 (100.0%)

* R= Reverse question

Table IV-18 showed that over half of the students (68.2%) agreed with the argument "The hypothesis is a temporary answer to the research problem made by scientist", 16.4% and 15.4% of the students disagreed and were uncertain with the argument respectively. For the reverse statements "The hypothesis is the final answer to the research problem which scientist got from the experiment", most students answered, "Disagree" (66.5%), followed by "Agree" (21.7%), and "Uncertain" (11.0%). Therefore, the results indicated that Thai seventh-grade students were aware that the hypothesis is a temporary answer to the research problem and it can be changed.

Youngsoo Kim (2010) suggested that hypothesis is the best tentative answer to the inquiry problem and was a generalized statement based on valid

grounds. Moreover, the hypothesis is formulated from the relationship between independent and dependent variables which must be verified through the scientific method. The survey results of Thai seventh grade students' awareness of scientific hypothesis showed that most of the students have correctly understood that hypothesis (1) is formulated from the valid grounds, (2) must be verified in a scientific way even though it is made by the scientist, (3) is a testable statement, (4) is incomplete, and (5) can be changed. Moreover, the findings also revealed that they did not understand the idea that scientific hypothesis stated by showing the relationships between independent and dependent variables. The results conform to Eom (2012) but conflicted with Yum (2012) who reported that Korean Middle School students have correctly perceived with all concepts of a scientific hypothesis.

An investigation or experiment usually being with the problem that needs solving or a decision (Richard, 2003). Richard stated "We investigate to determine if cause and effect relationships exist between things. By deliberately changing one variable in an investigation, another may change as a result." Hence, a process of formulating hypothesis is the heart of investigation because it leads to a good experimental design. Normally, we usually state the hypothesis before any investigation or experiment. As the formulating hypothesis process must start with extracting the variables from inquiry problem and used the extracted variables to formulate a hypothesis, we can state that hypothesis is formulated from the relationship between the independent and the dependent variables. This sense concurs with the hypothesis's definition given by AASPS assessment which is defined as a "… testable generation which stated the relationship between two selected variables under specific conditions" (German, 1996: Missouri Department of Elementary and Secondary Education, 1991). However, the survey results indicated that that Thai-seventh grade students were unaware of the idea that scientific hypothesis is stated by showing the relationships between two variables.

The possible reason can be explained by the Middle School I Science textbook which did not focus on extraction of related variables to formulate hypothesis but focus on the extracted variable in the experimenting process.

4. Ability to Formulate Scientific Hypothesis

The survey results came from Part 6: Ability to formulate scientific hypothesis of the questionnaire. The students were asked to formulate a scientific hypothesis in a giving scientific question "Why are Ixora flowers at my home blossoming more than Ixora flowers at my school?" The Criteria for evaluating the ability to formulate scientific hypothesis (Kim, 2010) was used to evaluate the students' ability to formulate scientific hypothesis. The survey results are classified into five parts as follows:

4.1. Ability to Formulate a Scientific Hypothesis as an Answer to the Inquiry Question

The survey results of Thai seventh-grade students' ability to formulate a hypothesis as an answer to the inquiry question were shown in Table IV-19.

Table IV-19. Frequencies and percentages for Thai seventh-grade students' ability to formulate a scientific hypothesis as an answer to the inquiry question

Answer	Number of students (%)
1. Present hypothesis as an answer to inquiry question	209 (74.4%)
2) Present hypothesis as an answer to other inquiry question	32 (11.3%)
3) Restatement of the phenomenon or inquiry problem	19 (6.8%)
4) Present other phenomena or inquiry problem	14 (5.0%)
5) I do not know	3 (1.1%)
6) No answer	4 (1.4%)

Total	281 (100.0%)

According to Table IV-19, Two hundred and nine Thai seventh-grade students (74.4%) could formulate a scientific hypothesis as an answer to inquiry question, followed by 11.3% of the students who formulated hypothesis as an answer to other inquiry question, 6.8% of the students who formulated a hypothesis which restated the phenomenon or inquiry problem, 5.0% of the students who formulated hypothesis which presented other phenomena or inquiry problem, 1.1% of the students who did not know how to formulate a scientific hypothesis, and 1.4% of the students who did not answer.

The survey results indicated that over 70% of the students could formulate a scientific hypothesis as an answer to inquiry question while only 25.6% of the students lacked ability in this skill. Additionally, 209 students were analyzed in other parts.

4.2. Ability to Formulate a Scientific Hypothesis Which Present the Relationship between the Independent and Dependent Variables

About half of the students (56.0%) formulated a scientific hypothesis which presented only one independent variable, followed by 23.4% of the students who presented many independent variables while a few of the students (8.1%) formulated a hypothesis which presented a relationship between multiple independent variables and one dependent variable. Only 12.4% of the students formulated a hypothesis which presented a relationship between one independent variable and one dependent variable conforming to the inquiry question (see Table IV-20).

Table IV-20. Frequencies and percentages for Thai seventh-grade students' ability to formulate a scientific hypothesis which presents the relationship among variables

Answer	Number of students (%)
Present a relationship between one independent variable and one dependent variable conforming to the inquiry question	26 (12.4%)
Present an relationship between multiple independent variables and one dependent variable	17. (8.1%)
Present only one independent variable	117 (56.0%)
Present many independent variables	49 (23.4%)
Total	209 (100%)

4.3. Ability to Formulate a Testable Scientific Hypothesis

The results of Thai seventh-grade student's ability to formulate a testable scientific hypothesis were shown in Table IV-21.

Table IV-21. Frequencies and percentages for Thai seventh-grade students' ability to formulate a testable scientific hypothesis

Answer	Number of students (%)
Testable	116 (55.5%)
Untestable	93 (44.5%)
Total	209 (100%)

Many educators accepted that a testable hypothesis is a statement of the relationship between two selected variables under the inquiry problem (Quin & George, 1975; German & Odom, 1996). In Fact, a testable hypothesis must include

both of independent and dependent variables, especially, all variables must be clear to measure, control or manipulate.

As Table IV-21 showed that more than half of Thai seventh-grade students (55.5%) had the ability to formulate a scientific hypothesis while 44.5% of the students could not formulate a testable hypothesis. In addition, the majority of the students who could not formulate a testable hypothesis identified the abstract independent variable which was difficult to measure, control or manipulate; for instance, taking care, environment, abundance, etc.

4.4. Ability to Formulate a Scientific Hypothesis Based on Valid Grounds

The results of Thai seventh-grade student's ability to formulate a scientific hypothesis based on valid grounds were showed in Table IV-22.

IV-22. Frequencies and percentages for Thai seventh-grade students' ability to formulate a scientific hypothesis based on valid grounds

Answer	Number of students (%)
Present the reasonable grounds	105 (50.2%)
Present the unreasonable grounds	71 (34.0%)
Explanation of the hypothesis	24 (11.3%)
Restatement of hypothesis	2 (1.0%)
No evidence	7 (3.3%)
Total	209 (100%)

According to Table IV-22, a half of the students (50.2%) could formulate a hypothesis which presented the reasonable grounds while about 30% of the students presented unreasonable grounds, about 10% explained the

hypothesis, 3.3% did not present any evidence, and only 1% presented a restated hypothesis.

Hence, approximately 50% of the Thai seventh-grade students were able to formulate a hypothesis based on their valid ground or previous knowledge while about 40% of them presented unreasonable grounds. The reason why the majority of the students could present the reasonable ground might be because the scientific question in the questionnaire is always found in the daily life and presented in many science textbooks. Therefore, the students had experiences with it and understood about the problem very well.

4.5. Ability to Formulate a Generalizing Scientific Hypothesis

The results of Thai seventh-grade student's ability to formulate a generalizing scientific hypothesis were shown in Table IV-23.

Table IV-23. Frequencies and percentages for Thai seventh-grade students' ability to formulate a generalizing scientific hypothesis

Answer	Number of students (%)
Generalized	19 (9.2%)
Ungeneralized	187 (90.8%)
Total	209 (100%)

For the survey results which presented in Table IV-32, less than 10% of Thai seventh-grade students could formulate a hypothesis in a general form while a huge number of Thai seventh grade students (90.8%) could not formulate a hypothesis in a general form.

Generally, scientists prefer to generate a generalizing hypothesis to describe an observed pattern in nature or phenomena. This sense is supported by Strode (2015) who argued that “We often use generalizing hypotheses to summarize patterns we observe in nature, and we can refer to these types of hypotheses as immature laws (generalizing hypothesis). If the generalizations hold true over and over again, they become established laws of nature." However, most of the students could not formulate a generalizing hypothesis. The reason for this case is the inquiry question in Part 6 of the questionnaire, “Why are Ixora flowers at my home blossoming more than Ixora flowers at my school?”, is too specific (specific case). Hence, the students could not generate a generalizing hypothesis from the specific case.

In sum, the results indicated that Thai seventh grade students could formulate a scientific hypothesis as an answer to the inquiry question. The results conflicted with Plangsri (2011) who reported that the majority of seventh-grade students lacked the ability to formulate a hypothesis from the inquiry question. Moreover, the Thai seventh grade students could not formulate a hypothesis which presents a relationship between one independent variable and one dependent variable. The findings were similar to what Germann and Odam (1996) reported that seventh-grade students did not perform well in identifying variables. The problem might be because Thai science curriculum pays attention to designing the experiments and process of testing more than formulating hypothesis process. Additionally, half of the students had the ability to formulate a hypothesis based on valid grounds. For the result of Thai seventh grade students had ability to formulate a testable hypothesis, the finding conflicted with Yum (2012) and Eom (2012) reported that Korean students had poor ability to formulate a testable hypothesis.

According to our previous study, the results indicated that Thai seventh-grade students were aware that scientific hypothesis is formulated from the valid ground. Moreover, they were aware that the hypothesis is a testable statement

which must be verified in a scientific way. They thought that hypothesis is incomplete and can be changed. However, in the results of the students' ability to formulate hypothesis indicated that about 50% Thai seventh-grade students had the ability to formulate a hypothesis. Hence, we can state that students understood in the aspects of scientific hypothesis but they did not perform well on formulating hypothesis. The results are consistent with what has been previously reported by many educators (Singpun, 2000; Nakthong, 2007; Plagsri, 2010; Eom 2012; German and Odom, 1996). This problem might be because, in Thailand, the curriculum had been dominated by the hypotheco-deductive model. Generally, the classroom version of this view is the stepwise scientific method which includes making observations, formulating a hypothesis, deducing consequences from the hypothesis, making observations to test the consequences, and accepting or rejecting the hypothesis based on the observation (Grandy & Duschl, 2007). Oh (2010) also argued that this inquiry model mainly concentrated on designing the experiment and validating a hypothesis by experimental results while the process of generating a hypothesis was always ignored.

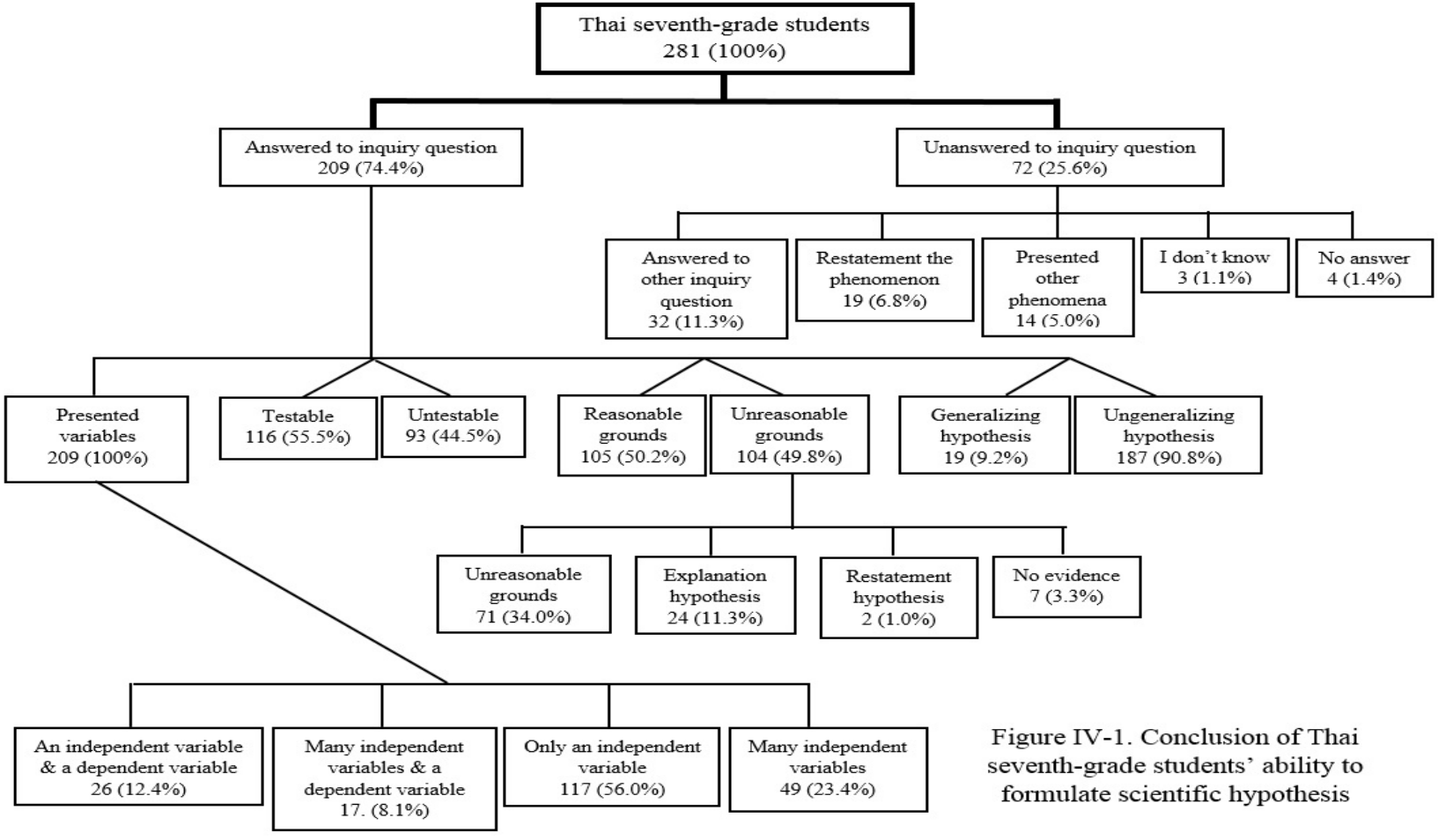

Figure IV-1. Conclusion of Thai seventh-grade students' ability to formulate scientific hypothesis

V. CONCLUSION AND SUGGESTION

The purpose of this study was to survey the Thai seventh-grade students' awareness of and ability to formulate a scientific hypothesis. A total of 285 Thai seventh graders from three Thai public schools were asked to respond the questionnaire Awareness of and Ability to Formulate Scientific Hypothesis (Thai version). This part is categorized into two topics as follows: 1. Conclusion and Suggestions, and 2. Limitations of the Research.

1. Conclusion and Suggestion

The results of the Thai seventh-grade students' awareness of nature of scientific knowledge indicated that Thai seventh-grade students were aware that scientific knowledge is created from the reasonable ground, is incomplete, and can be changed. Moreover, the students thought that the scientific knowledge is discovered by scientists. To improve the students understanding of nature of science (NOS) can be implemented by teaching according to scientific inquiry approach with an explicit and reflective instructional approach (Khamkaew, 2015).

For the results of Thai seventh-grade students' awareness of scientific method, most of Thai seventh-grade students have heard about 'hypothesis', 'prediction', and 'conclusion' while a half of them have heard about 'assumption'. Furthermore, they thought that they understood about 'hypothesis', 'prediction', and 'conclusion', but did not understand about 'assumption'. The students have heard the scientific method terms from science class, school teachers, books, and mass communication. The students could not distinguish 'hypothesis' from 'assumption, 'prediction' and 'conclusion' in a

giving definition. Moreover, they could not distinguish 'hypothesis' from 'prediction' in a giving scientific situation. The findings suggested that Thai seventh-grade students were confused with the scientific method terms, especially, the difference between 'prediction' and 'hypothesis'. Regarding the results of the scientific method, less than five percent of Thai seventh-grade students could correctly sequence the steps of the scientific method. Most of them were aware that scientific method started with asking the question, and also thought that the second step was prediction process, not variable extraction process. Hence, to solve this problem, the Middle school 1 science text book should not only add more contents about formulating hypothesis and how to extract variable but also explain clearly in each scientific process. Moreover, the teacher should particularly emphasize on the difference between hypothesis and prediction which are easy to confuse.

For the results of Thai seventh-grade students' awareness of scientific hypothesis, the students were aware that hypothesis is formulated from the valid grounds. They knew that hypothesis is a testable statement which must be verified in a scientific way. Moreover, they thought that hypothesis is incomplete and can be changed. However, they were unaware of the idea that hypothesis is formulated from the relationship between independent and dependent variables. Lastly, the results of Thai seventh-grade students' ability to formulate scientific hypothesis indicated that that most of the students had the ability to formulate a scientific hypothesis as an answer to inquiry question and state a hypothesis which presented only one independent variable. Moreover, about half of the students could formulate a testable hypothesis and present the valid grounds which they used to formulate the hypothesis. However, they lacked the ability to formulate a generalizing hypothesis. Hence, we can state that students understood in the aspects of scientific hypothesis but they did not perform well on formulating scientific hypothesis. Therefore, Thai seventh-

grade students need more practice in the variable extraction process. Particularly, a new teaching method for enhancing students' awareness of and ability to formulate a scientific hypothesis is required to be developed.

2. Limitations of the Research

There were some limitations in this study. Firstly, the researcher is not fluent in the Korean language so it limited in being able to read and deeply understand about some contents, especially the questionnaire which originally created in the Korean language. Secondly, since the Part 6 of the questionnaire designed to survey the students' ability to formulate a scientific hypothesis; the students were asked to formulate a hypothesis from the inquiry question. In general, an inquiry question which leads to the formulation of generalizing hypothesis, the question should be a general question form. However, in this study, the inquiry question was too specific so almost of the students could not formulate a generalizing hypothesis. Therefore, the inquiry question must be revised. Thirdly, collecting data of this study was planned to collect in the second semester of the academic year, because of the limitation of the time and school schedule, the schools did not allow the researcher to collect the data from the nine-grade or eighth-grade students, so our subjects were changed to seventh-grade students. This limitation affected the study results which limited the representation of entire Thai Middle school students' awareness of and ability to formulate scientific hypothesis.

VI. RECOMMENDATION FOR FUTURE STUDY

The study is about Thai seventh-grade students' awareness of and ability to formulate a scientific hypothesis. The investigation found that the students were still confused with the steps of the scientific method. They could not distinguish 'hypothesis' from 'prediction'. Moreover, the students did not perform well in formulating hypothesis. In order to extend this study, the recommendation for future study are suggested as below:

1. The inquiry question in part 6 of the questionnaire was too specific which the subjects could not formulate a generalizing hypothesis. Therefore, the inquiry question must be revised.
2. To study about teachers' awareness of and ability to formulate scientific hypothesis.
3. To study about the teaching approach that science teacher usually uses in their class for teaching the scientific method, especially, formulating hypothesis process and how that they deal with hypothesis content in textbooks and what the contents convey to the students.
4. To study about the comparison of middle school and high school students' awareness of and ability to formulate scientific hypothesis. The results will be used to develop the teaching strategies for middle school level which provides the prerequisite knowledge for using in the higher grade.
5. To study the creation of teaching approach for improving students' awareness of scientific hypothesis and ability to formulate it.
6. To study about how to help the students to have the ability to formulate a generalizing hypothesis and what kind of questions which lead to the formulation of a generalizing hypothesis.

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APPENDIX

Middle School Students' Awareness of and Ability to formulate Scientific Hypothesis

Questionnaire

Introduction

- The questionnaire aims to access Thai 7th grade students about the (1) awareness of scientific hypothesis; (2) ability to formulate a scientific hypothesis; (3) awareness of nature of scientific knowledge; (4) awareness of scientific method.
- The questionnaire consists of 6 parts, totally 8 pages (include front cover)
- The information you provide in this questionnaire is intended for improving the teaching approaches and strategies for science subjects and students formulating a scientific hypothesis.
- The results of personal information are not released and reflected your school grades. So, please, answer the question carefully and honestly.
- Total time: 30 minutes

School name: _____

Semester: 2 Academic Year: 2016

January 2017

Seoul National University, Republic of Korea

Department of Biology Education

[Part I] Nature of Scientific Knowledge

Direction: Please check ✓ the box (Agree, Disagree, and Uncertain) that corresponds with your opinion in each given statement.

Statement	Agree	Disagree	Uncertain
1. Scientific knowledge already exists in nature, discovered by scientists.			
2. When a scientist explains a natural phenomenon, even if there is no supporting evidence, it is ok.			
3. Scientific knowledge fully explains the natural world.			
4. Scientific knowledge is obtained through the scientific method, so even if time goes by, it won't change.			
5. Scientific knowledge is made by scientists.			
6. When a scientist explains a natural phenomenon, the explanation has to be supported by evidence.			
7. Scientific knowledge cannot fully explain the natural world.			
8. Scientific knowledge has been achieved through discussion and review by a group of scientists, so it does not change over time.			
9. In order to explain natural phenomena, scientist discovers scientific knowledge that exists in nature			
10. When a scientist explains a natural phenomenon, that is plausible without any basis for it, we can accept as a scientific knowledge.			
11. Scientific knowledge is obtained through the scientific method, so there can be no errors.			
12. Scientific knowledge can change as new experimental evidence accumulates.			
13. Scientific knowledge is an explanation of the natural phenomenon which is made by scientists.			
14. A scientist explains based on his or her knowledge when explaining a natural phenomenon.			
15. Scientific knowledge may be incomplete because of his or her errors in conducting research.			
16. Scientific knowledge looks unchangeable, but it is changeable.			

[Part 2] Scientific Method

Direction: Read the following story carefully and answer the following questions.

Mali's Story

Mali is a 9th-grade student. She always spends most of her free time to read books and do her homework on her desk in her bedroom. Because Mali is a plant lover so she got an idea that "It will be better if I place a flowering plant on my desk". Then, Mali bought a flowering plant from a plant shop near her home and placed it on her desk. Several days later, she observed that the flowering plant grew slowly and weak. Mali wondered why the flowering plant grows slowly, so, she determined to use the scientific method to solve this problem.

Mali's scientific Method

The following statements present the step of scientific process.

ⓐ Light is the one factor of plant growth. Because I placed my flowering plant on the desk which didn't get enough light, so it grows slowly.

ⓑ After I read many books, I found out that my plant needs light, moisture, nutrients and room temperature for growth. I did only watering, applying fertilizer and placed it on my desk in my bedroom which did get enough light.

ⓒ Why did my plant grow slowly?

ⓓ Because I placed my flowering plant on the desk which didn't get enough light, so it grows slowly. If I place it near the windows, my plant will grow well.

ⓔ I found out that the second flowering plant which was put near the windows grew faster than the flowering plant which was put on the desk. This result matched to my thought in the beginning that Because I placed my flowering plant on the desk which didn't get enough light, so it grows slowly.

ⓕ I started my experiment by buying two flowering plants from the same plant shop which were similar in size, height, and characteristics (same condition). Then, I put the first flowering plant on the desk and the second one near the windows which could get enough sunlight. I controlled moisture, nutrient, and temperature. After that, I always observe and record the results every day. Finally, I found out the different results between them

In the story above, please put the inquiry process in the correct order of the scientific method

( ) → ( ) → ( ) → ( ) → ( ) → ( )

[Part 3] Scientific Method Terms

Direction: The following are questions about scientific method terms: assumptions, hypotheses, predictions, and conclusions. Read the following and answer the question.

1) Have you ever heard about the following scientific method terms?

※ Please check ✓ "Yes" if you have heard and "No" if you have not heard.

	Yes	**No**
Assumptions	ⓐ	ⓑ
Hypotheses	ⓐ	ⓑ
Predictions	ⓐ	ⓑ
Conclusions	ⓐ	ⓑ

1) If you have heard them from question 1, how did you hear about the scientific method terms?

※ Please check ✓ Ⓐ,Ⓑ,Ⓒ,Ⓓ or Ⓔ based on how you heard about the scientific method terms.

	In science class at school	From school teacher	From friend(s)	From books (books, magazine, journal, etc.)	Mass communication (TV, radio newspaper etc.)	Other
Assumption	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	( )
Hypotheses	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	( )
Prediction	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	( )
Conclusion	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	( )

2) How well do you know each of following scientific method terms?

※ For each scientific term, please rate and check □Ⓐ, Ⓑ, or Ⓒ that corresponds with your opinion in each given statement.

	I understand	**I understand it a little**	**I don't understand**
Assumption	Ⓐ	Ⓑ	Ⓒ
Hypotheses	Ⓐ	Ⓑ	Ⓒ
Prediction	Ⓐ	Ⓑ	Ⓒ
Conclusion	Ⓐ	Ⓑ	Ⓒ

[Part 4] Scientific hypothesis

Direction: The following statements describe a scientific hypothesis in scientific process. For each statement, please check ☐Agree, Disagree, or Uncertain that corresponds with your opinion in each given statement.

Statement	Agree	Disagree	Uncertain
1. The hypothesis is a temporary answer to the research problem, so it does not need to be judged right or wrong.			
2. The hypothesis is inferring about what will happen or be observed in a certain experimental condition on the basis of scientist background knowledge.			
3. The hypothesis is the results of the experiment that will be judged whether accept or reject the temporary answer			
4. The scientist formulates a hypothesis of the research problem from his or her previous knowledge or experience.			
5. The hypothesis is expressed by indicating the relationship between certain natural phenomena and the factors influencing the natural phenomena.			
6. The hypothesis must be testable through experimentation.			
7. The hypothesis must be verified in a scientific way, even though it is made by the scientist.			
8. The hypothesis which made by a scientist is always right.			
9. The hypothesis is a temporary answer to the research problem which made by a scientist.			
10. The hypothesis is a statement about what will happen or be observed in a certain experimental condition.			
11. When a scientist formulates a hypothesis of the research problem, he or she can make it plausible even if it is not based on the previous knowledge.			
12. The hypothesis is expressed by indicating the relationship between the factors that affect certain natural phenomena and the natural phenomena that are affected.			
13. The hypothesis must be judged right and wrong through experiments.			
14. When the scientists make the hypothesis, they think that it is the best answer to the research problem, so it does not need any verification.			
15. The hypothesis made by a scientist may not be true.			
16. The hypothesis is the final answer to the research problem which scientist got from the experiment.			

[Part 5] Confusing scientific terminology; hypotheses, assumption, conclusion, prediction, and inquiry question.

Direction: Read each following statement, please check ☐whether the underlined statements are hypotheses Ⓐ, assumption Ⓑ, conclusion Ⓒ, prediction Ⓓ, inquiry question Ⓔ or I do not know Ⓕ.

Question 1

Mr. Arthit who is the poultry farm's owner. He observed and found that his chickens were sick. The symptoms were similar to the Beriberi which started with signs of fatigue, leg's weakness, and sometimes completely paralyzed. However, the symptoms came on a short period of time, sick chickens began to recover without any treatment. Mr. Arthit wondered why the symptoms of sick chickens had improved suddenly. He tried to analyze this phenomenon and found that it was because he had changed the chicken feed from polished rice to brown rice.

So, Mr. Arthit got a notion that **① "Because I had fed brown rice to chickens, symptoms were improved."** And if this is true, **② "during the same period, chickens that are fed only polished rice will be sick, while chickens that are fed only brown rice will be healthy."** After that, Mr. Arthit started conducting his experiment for checking his notion, chickens that eat only polished rich will be sick, chickens that eat only brown rice will be healthy, under the condition that **③ "chickens in his farm were fed only from human"**. After the experiment, he found out that **④ "brown rice contains many nutrients which alleviate or prevent the symptoms."** From the result of his experiment, Mr. Arthit discovered that the result matches his notion in the beginning.

	Hypothesis	Assumption	Conclusion	Prediction	Inquiry question	I don't know
Statement ①	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ
Statement ②	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ③	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ④	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ

Question 2

Mr. Phupha, who is a scientist, is studying gazelles in the savannas, Kenya. During the study, he observed the unusual behavior of the gazelle that when cheetahs appear, gazelles always jump and show the white rumps. So Mr. Phupha wondered why gazelles always do this behavior and thought that he could find the possible answer from the previous research.

He thought ① **"Gazelles jump high because they want to keep their calves safe from the cheetahs"**. If this is true, ② **"when cheetahs appear, female gazelles which have calves will jump higher than female gazelles which don't have calves"**. However, after his studying, there was no significant difference in the number of jumping between the female gazelles. Base on this result, Mr. Phupha found that ③ **"when cheetahs appeared, there was no difference whether female gazelles have calves or not".** So, Mr. Phupha thought that ④ **"high jumping of gazelles is for showing the ability and power to the cheetah"**. If this is true, ⑤ **"low jumping gazelles will be attacked more than high jumping gazelles"**. After long observation, Mr. Phupha found out the low jumping gazelles were attacked by cheetahs much more than high jumping gazelles. Then, he decided that ⑥ **"because the gazelles want to show their ability and power to cheetahs which want to attack them, so they always show the high jumping behavior when cheetahs appear."**

	Hypothesis	Assumption	Conclusion	Prediction	Inquiry question	I don't know
Statement ①	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ
Statement ②	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ③	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ④	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ⑤	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ
Statement ⑥	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓔ

[Part 6] Ability to formulate scientific hypothesis

Direction: Please read the inquiry situation and set a hypothesis from the Kaew's question.

Inquiry Situation: Ixora

Ixora is one of the specific flowers which students give the teachers on the Teacher Respect Day because it symbolizes sharp wit. The day before Teacher Respect Day, students have to prepare the flower tray for teacher respect ceremony. Kaew was preparing the Ixora flower for the ceremony at her home, and she observed that Ixora flowers at her home were blossoming more than Ixora flowers at her school.

Question is formulated by Kaew

※ **Why are Ixora flowers at my home blossoming more than Ixora flowers at my school?**

1) Please formulate a hypothesis from Kaew's question.

2) From the question 1) please write the basis information (background, knowledge, experience etc.) that you used to formulate your hypothesis.

แบบวัดความตระหนักและความสามารถในการสร้างสมมติฐานทางวิทยาศาสตร์ของนักเรียนชั้นมัธยมศึกษาตอนต้น

(Thai Middle School Students' Awareness of and Ability to formulate Scientific Hypothesis)

คำชี้แจง

- แบบสอบถามฉบับนี้มีจุดประสงค์เพื่อประเมินนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1 ในเรื่อง
    1. ความตระหนักเกี่ยวกับสมมติฐานทางวิทยาศาสตร์
    2. ความสามารถในการสร้างสมมติฐานทางวิทยาศาสตร์
    3. ความตระหนักเกี่ยวกับธรรมชาติของวิทยาศาสตร์
    4. ความตะหนักเกี่ยวกับวิธีการทางวิทยาศาสตร์
- แบบสอบถามฉบับนี้มีทั้งหมด 6 ตอน จำนวน 8 หน้า ครอบคลุมเนื้อหาทางวิทยาศาสตร์ทั้งหมด 3 เรื่อง ได้แก่ ธรรมชาติของความรู้ทางวิทยาศาสตร์ วิธีการทางวิทยาศาสตร์ และสมมติฐานทางวิทยาศาสตร์
- ข้อมูลที่ได้จากแบบวัดนี้จะเป็นประโยชน์ต่อการพัฒนาเทคนิควิธีการสอน เพื่อส่งเสริมให้นักเรียนมีความสามารถในการสร้างสมมมติฐานที่ดีต่อไป

- <u>คะแนนที่ได้จากแบบสอบถามนี้จะถูกเก็บแบบความลับและไม่ส่งผลต่อเกรดในโรงเรียน</u>
  <u>ดังนั้นกรุณาตอบแบบสอบถามด้วยความซื่อสัตย์และเต็มความสามารถ</u>
- เวลาในการทำข้อสอบทั้งหมด 30 นาที

โรงเรียน_____

_____

ภาคเรียนที่ 2 ปีการศึกษา 2559

มกราคม พ.ศ. ๒๕๖๐

มหาวิทยาลัยแห่งชาติโซล ประเทศเกาหลีใต้,

ภาควิชาการสอนชีววิทยา

ตอนที่ 1 ความเข้าใจเกี่ยวกับธรรมชาติของความรู้ทางวิทยาศาสตร์

<u>คำชี้แจง</u> โปรดอ่านข้อความแล้วทำเครื่องหมาย ☐ลงในช่อง เห็นด้วย ไม่เห็นด้วย และไม่แน่ใจ ที่สอดคล้องกับความเห็นของนักเรียนมากที่สุดเพียงช่องเดียว

ข้อความ	เห็นด้วย	ไม่เห็นด้วย	ไม่แน่ใจ
1. ความรู้ทางวิทยาศาสตร์มีอยู่แล้วในธรรมชาติโดยมีนักวิทยาศาสตร์เป็นผู้ค้นพบ			
2. นักวิทยาศาสตร์สามารถอธิบายปรากฏการณ์ทางธรรมชาติโดยไม่ต้องมีหลักฐานสนับสนุน			

3. ความรู้ทางวิทยาศาสตร์สามารถอธิบายเหตุการณ์ปรากฏการณ์ได้ทั้งหมด			
4. ความรู้ทางวิทยาศาสตร์ได้มาจากวิธีการทางวิทยาศาสตร์ ดังนั้นจึงไม่สามารถเปลี่ยนแปลงได้			
5. ความรู้ทางวิทยาศาสตร์ถูกสร้างขึ้นโดยนักวิทยาศาสตร์			
6. เมื่อนักวิทยาศาสตร์อธิบายปรากฏการณ์ทางธรรมชาติ คำอธิบายนั้นจะต้องได้รับการยืนยันด้วยหลักฐาน			
7. ความรู้ทางวิทยาศาสตร์ไม่สามารถอธิบายเหตุการณ์ปรากฏการณ์ได้ทั้งหมด			
8. ความรู้ทางวิทยาศาสตร์ได้มาจากการอภิปรายร่วมกันของกลุ่มนักวิทยาศาสตร์ ดังนั้นจึงไม่เปลี่ยนแปลงตามการเวลา			
9. นักวิทยาศาสตร์ค้นพบความรู้ทางวิทยาศาสตร์ที่มีอยู่แล้วในธรรมชาติ เพื่อนำมาอธิบายปรากฏการณ์ทางธรรมชาติ			
10. เมื่อนักวิทยาศาสตร์อธิบายปรากฏการณ์ทางธรรมชาติ โดยให้คำอธิบายที่มีความสมเหตุสมผล แม้ว่าคำอธิบายนั้นจะไม่มีหลักพื้นฐานที่เกี่ยวข้องกับปรากฏการณ์ที่เกิดขึ้น เราก็สามารถยอมรับคำอธิบายนั้นเป็นความรู้ทางวิทยาศาสตร์ได้			
11. ความรู้ทางวิทยาศาสตร์ได้มาจากวิธีการทางวิทยาศาสตร์ ดังนั้นจึงไม่มีความผิดพลาด			
12. ความรู้ทางวิทยาศาสตร์สามารถเปลี่ยนแปลงได้เมื่อมีพยานหลักฐานใหม่มาสนับสนุนเพิ่มเติม			
13. ความรู้ทางวิทยาศาสตร์ คือ คำอธิบายปรากฏการณ์ทางธรรมชาติที่ถูกสร้างขึ้นโดยนักวิทยาศาสตร์			
14. นักวิทยาศาสตร์อธิบายปรากฏการณ์ทางธรรมชาติ โดยอาศัยความรู้พื้นฐานของตนเอง ซึ่งแต่ละคนก็มีความรู้แตกต่างกัน			
15. ความรู้ทางวิทยาศาสตร์อาจไม่สมบูรณ์ เนื่องจากความผิดพลาดของนักวิทยาศาสตร์แต่ละคนที่อาจจะเกิดขึ้นในระหว่างการทำงาน			

16. ความรู้ทางวิทยาศาสตร์ดูเหมือนเปลี่ยนแปลงไม่ได้ แต่ในความเป็นจริงแล้วสามารถเปลี่ยนแปลงได้			

ตอนที่ 2 วิธีการทางวิทยาศาสตร์

คำชี้แจง จงอ่านสถานการณ์ที่เกี่ยวข้องกับวิธีการทางวิทยาศาสตร์

ปัญหาของมะลิ

แ ้านล่าง

เมื่อครั้งที่มะลิเรียนอยู่ชั้น ม.ต้น มะลิใช้เวลาส่วนใหญ่ไปกับการทำการบ้านและอ่านหนังสือบนโต๊ะหนังสือของเธอ ด้วยความที่มะลิเป็นคนที่รักต้นไม้ มะลิจึงเกิดความคิดขึ้นมาว่า มันน่าจะดีถ้านำต้นไม้ที่มีดอกไม้มาวางบนโต๊ะอ่านหนังสือ

วิธีการทางวิทยาศาสตร์ของมะลิ

ออกดอกจากร้านขายต้นไม้ที่อยู่ตรงข้ามบ้านมา 1 ต้น และนำต้นมาวางบนโต๊ะอ่านหนังสือ และคอยดูแลมัน แต่เมื่อเวลาผ่านไปหลายวัน มะลิสังเกตเห็นว่าดอกของต้นไม้ที่วางอยู่บนโต๊ะหนังสือเจริญเติบโตไม่ดีเท่าที่ควร เธอจึงเกิดความสงสัยขึ้นมาว่า เพราะเหตุใดจึงเป็นเช่นนี้ ดังนั้นเธอจึงตัดสินใจค้นหาคำตอบด้วยวิธีการทางวิทยาศาสตร์

ข้อความด้านล่างแสดงลำดับวิธีการทางวิทยาศาสตร์

ⓐ ต้นไม้ต้องการแสงที่เพียงพอในการเจริญเติบโต
การที่ฉันวางต้นไม้ไว้บนโต๊ะหนังสือทำให้ได้รับแสงไม่เพียงพอ
ดังนั้นจึงทำให้ดอกไม้เจริญเติบโตไม่ดีเท่าที่ควร
ⓑ เมื่อฉันอ่านหนังสือที่เกี่ยวของกับการปลูกไม้ดอก ฉันจึงทราบว่า ต้นไม้ของฉัน
ต้องการแสง น้ำ และสารอาหารที่เพียงพอ และเจริญเติบโตได้ดีที่อุณหภูมิห้อง!
ซึ่งฉันทำเพียงแค่รดน้ำและใส่ปุ๋ย และวางมันไว้ในห้องเท่านั้น
แต่ว่าต้นไม้ไม่ได้รับแสงอย่างเพียงพอเพราะฉันวางมันไว้ในห้อง
ⓒ เพราะเหตุใดดอกไม้จึงเจริญเติบโตไม่ดีเท่าที่ควร?

ⓓ ฉันคิดว่าสาเหตุที่ดอกไม้เจริญเติบโตไม่ดีเท่าที่ควร
เพราะว่ามันได้รับแสงแดดไม่เพียงพอ ดังนั้น
ถ้าฉันวางต้นไม้ไว้บนโต๊ะซึ่งทำให้ได้รับแสงไม่เพียงพอทำ
จึงทำให้ดอกไม้เจริญเติบโตไม่ดีเท่าที่ควร
แต่ถ้าฉันวางไว้ใกล้หน้าต่างดอกไม้จะเจริญเติบโตได้ดี
ⓔ
ฉันพบว่าดอกไม้ของต้นไม้ที่ฉันวางไว้ตรงหน้าต่างเจริญเติบโตได้ดีกว่าดอกไม้ขอ
งต้นไม้ที่ฉันวางไว้บนโต๊ะหนังสือ ซึ่งสิ่งที่ฉันคิดไว้มันถูกต้อง!
ที่ว่าดอกไม้ของต้นไม้ที่วางไว้บนโต๊ะเจริญติบโตไม่ดีเท่าที่ควร
เนื่องจากได้รับแสดงที่ไม่เพียงพอ
ⓕ ฉันทำการทดลองโดยไปซื้อต้นไม้ 2 ต้น ที่มีทั้งขนาดและรูปร่างคล้ายกัน
และปลูกภายใต้เงื่อนไขเดียวกัน หลังจากนั้นฉันวางต้นแรกบนโต๊ะอ่านหนังสือ
และวางต้นที่สองตรงหน้าต่างบริเวณที่แสงแดดส่องถึง
หลังจากนั้นฉันจึงเริ่มทำการสังเกตการเจริญเติบโตของดอกไม้ของต้นไม้ทั้ง 2 ต้น
ซึ่งในระหว่างนี้ฉันรดน้ำ ใส่ปุ๋ย และวางมันไว้ในในอุณหภูมิที่เท่ากัน
เพื่อช่วยให้ต้นไม้สามารถเจริญเติบโตได้

จงเรียงลำดำขั้นตอนของวิธีการทางวิทยาศาสตร์ที่มะลิใช้ในการแก้ปัญหาให้ถูกต้อง

( ) → ( ) → ( ) → ( ) →
( ) → ( )

ตอนที่ 3 คำศัพท์เฉพาะทางวิทยาศาสตร์

คำชี้แจง

ให้นักเรียนอ่านและตอบคำถามเกี่ยวกับคำศัพท์เฉพาะทางวิทยาศาสตร์ ได้แก่ ข้อตกลงเบื้องต้น (Assumption), สมมติฐาน (Hypothesis), การพยากรณ์ (Prediction) และข้อสรุป (Conclusion)

1) นักเรียนเคยได้ยินเกี่ยวกับคำศัพท์เฉพาะทางวิทยาศาสตร์เหล่านี้หรือไม่

※จงเขียนเครื่องหมาย ✓ ลงในช่อง “เคยได้ยิน” ถ้านักเรียนเคยได้ยิน และ “ไม่เคยได้ยิน” ถ้านักเรียนไม่เคยได้ยิน

	เคยได้ยิน	**ไม่เคยได้ยิน**
ข้อตกลงเบื้องต้น (Assumption)		
สมมติฐาน (Hypothesis)		
การพยากรณ์ (Prediction)		
ข้อสรุป (Conclusion)		

2) จากข้อ 1) ถ้านักเรียนเคยได้ยิน

นักเรียนได้ยินคำศัพท์เฉพาะทางวิทยาศาสตร์เหล่านี้มากจากที่ใด

※จงเขียนเครื่องหมาย ✓ ลงในช่อง ⓐ, ⓑ, ⓒ, ⓓ หรือ ⓔ ที่สอดคล้องกับแหล่งที่นักเรียนเคยได้ยิน

	คาบเรียนวิทยาศาสตร์	ครูวิทยาศาสตร์	เพื่อน	สื่อสิ่งพิมพ์ (หนังสื	สื่อสารมวลชน (โทรทัศน์	แหล่งอื่น ๆ

				อ วารสาร นิตยสา ร เป็นต้น)	วิทยุหนังสือ พิมพ์ เป็นต้น)	
ข้อตกลงเบื้อ งต้น (Assumpti on)	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	( )
สมมติฐาน (Hypothesi s)	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	( )
การพยากร ณ์ (Prediction)	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	( )
ข้อสรุป (Conclusio n)	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	( )

3) นักเรียนเข้าใจความหมายของคำศัพท์เฉพาะทางวิทยาศาสตร์เหล่านี้ดีเพียงใด

※ จงเขียนเครื่องเหมาย □ลงในช่อง ฉันเข้าใจ, ฉันเข้าใจนิดหน่อย, ฉันไม่เข้าใจ ที่สอดคล้องกับความเข้าใจของนักเรียนมากที่สุด

	ฉันเข้าใจ	ฉันเข้าใจนิดหน่อย	ฉันไม่เข้าใจ
ข้อตกลงเบื้องต้น (Assumption)			
สมมติฐาน (Hypothesis)			
การพยากรณ์ (Prediction)			

ข้อสรุป (Conclusion)			

ตอนที่ 4 สมมติฐานทางวิทยาศาสตร์

คำชี้แจง โปรดอ่านข้อความแล้วทำเครื่องหมาย ☐ลงในช่อง เห็นด้วย, ไม่เห็นด้วย หรือ ไม่แน่ใจ ที่สอดคล้องกับความเห็นของนักเรียนมากที่สุดเพียงช่องเดียว

ข้อความ	เห็นด้วย	ไม่เห็นด้วย	ไม่แน่ใจ
1. สมมติฐาน คือ คำตอบที่ตั้งขึ้นชั่วคราวของปัญหา ดังนั้นจึงไม่จำเป็นต้องมีการตัดสินว่าถูกหรือผิด			
2. สมมติฐาน คือ การทำนาย หรือการคาดคะเนคำตอบ โดยอาศัยข้อมูลที่ได้จากการสังเกตหรือการทำซ้ำ ผ่านกระบวนการแปรความหมายของข้อมูลจากความสัมพันธ์ของตัวแปรภายใต้ความรู้ทางวิทยาศาสตร์			
3. สมมุติฐาน คือ การนำเอาข้อมูลที่ได้จากการสังเกต ค้นคว้า หรือการทดลอง มาพิจารณา เพื่อตัดสินว่าตรงกับคำตอบที่เราได้ตั้งไว้ล่วงหน้าหรือไม่			
4. นักวิทยาศาสตร์ สร้างสมมติฐานของปัญหาการวิจัย จากความรู้และประสบการณ์เดิมของตนเอง			
5. สมมติฐานเป็นข้อความที่แสดงความสัมพันธ์ระหว่างปรากฏการณ์ทางธรรมชาติที่มีแบบแผนแน่นอนและปัจจัยต่าง ๆ ที่มีอิทธิพลต่อปรากฏการณ์นั้น			
6. สมมติฐานจะต้องสามารถตรวจสอบได้จากการทดลอง			
7. สมมติฐานจะต้องถูกตรวจสอบด้วยวิธีการทางวิทยาศาสตร์ ถึงแม้ว่าจะถูกสร้างขึ้นโดยนักวิทยาศาสตร์ก็ตาม			
8. สมมติฐานที่ถูกสร้างโดยนักวิทยาศาสตร์นั้นถูกต้องเสมอ			
9. สมมติฐาน คือ			

คำตอบชั่วคราวของปัญหาวิจัยถูกสร้างขึ้นโดยนักวิทยาศาสตร์			
10. สมมติฐาน คือ การกล่าวเกี่ยวกับเหตุการณ์หรือปรากฏการณ์ที่จะเกิดขึ้นในอนาคต โดยอาศัยหลัก กฎ ทฤษฎี รวมทั้งข้อมูลที่ได้จากการสังเกตหรือจากประสบการณ์ที่เกิดซ้ำ ๆ			
11. นักวิทยาศาสตร์สามารถสร้างสมมติฐานของปัญหาวิจัยที่มีความสมเหตุสมผลได้ โดยไม่ต้องอาศัยความรู้เดิมของตนเอง			
12. สมมติฐาน แสดงออกมาในรูปของความสัมพันธ์ระหว่างปัจจัยต่าง ๆ ที่มีอิทธิพลต่อปรากฏการณ์ทางธรรมชาติที่ที่มีแบบแผนแน่นอน และปรากฏการณ์ทางธรรมชาติที่ได้รับอิทธิพลจากปัจจัยต่าง ๆ เหล่านั้น			
13. สมมติฐานจะถูกตัดสินว่าถูกหรือผิดจากการทดลอง			
14. เมื่อนักวิทยาศาสตร์สร้างสมมติฐาน นักวิทยาศาสตร์ถือว่าสมมติฐานที่ตนสร้างขึ้นนั้นเป็นคำตอบที่ดีที่สุด ดังนั้นจึงไม่จำเป็นต้องได้รับการพิสูจน์ความจริง			
15. สมมติฐานที่ถูกสร้างโดยนักวิทยาศาสตร์อาจไม่ถูกต้องเสมอไป			
16. สมมติฐาน คือ ผลลัพธ์สุดท้ายของปัญหาการวิจัยที่นักวิทยาศาสตร์ได้มาจากการทดลอง			

ตอนที่ 5 ความสับสนเกี่ยวกับคำศัพท์เฉพาะทางวิทยาศาสตร์ ได้แก่ สมมติฐาน (Hypothesis), ข้อตกลงเบื้องต้น (Assumption), ข้อสรุป (Conclusion), การพยากรณ์ (Prediction) และ คำถามการวิจัย (Inquiry question)

คำชี้แจง

จงจัดประเภทคำศัพท์เฉพาะทางวิทยาศาสตร์ของ**ประโยคที่ขีดเส้นใต้**ในสถานการณ์ด้านล่าง โดยเขียนเครื่องหมาย ☐ ลงในช่องที่สอดล้องกับสมมติฐาน ⓐ , ข้อตกลงเบื้องต้น ⓑ, ข้อสรุป ⓒ, การพยากรณ์ ⓓ, คำถามการวิจัย ⓔ หรือ ฉันไม่รู้ ⓕ ตามความเห็นของนักเรียน

คำถามที่ 1

นายอาทิตย์เป็นเจ้าของฟาร์มไก่แห่งหนึ่ง เขาสังเกตเห็นว่ามีไก่จำนวนมากเกิดล้มป่วย โดยลักษณะอาการนั้นคล้ายกับโรคเหน็บชา (Beriberi) ซึ่งลักษณะอาการที่พบนั้น เริ่มต้นจาก ไก่มีอาการอิดโรย ขาอ่อนแรง และบางครั้งเป็นอัมพาต แต่อย่างไรก็ตามนายอาทิตย์พบว่าอาการป่วยเหล่านั้นเกิดขึ้นเพียงแค่ระยะเวลาสั้น ๆ ไก่หายป่วยได้เองแม้จะไม่ได้รับการรักษา นายอาทิตย์จึงเกิดความสงสัยว่า ทำไมอาการป่วยของไก่จึงหายไปเองอย่างรวดเร็ว เขาจึงพยายามเวิเคราะห์หาสาเหตุของปรากฏการณ์ที่เกิดขึ้น จนในที่สุดเขาก็พบว่าตัวเองนั้นได้เปลี่ยนชนิดของอาหารไก่ จากที่เคยให้ข้าวขาว (ข้าวขัดสี) มาเป็นข้าวซ้อมมือแทน

ดังนั้นนายอาทิตย์จึงเกิดความคิดขึ้นมาว่า ① **“ฉันเปลี่ยนมาให้ไก่กินข้าวซ้อมมือ ดังนั้นอาการป่วยของไก่จึงบรรเทาลง”** และถ้าสิ่งที่ฉันคิดถูกต้องแล้วนั้น ② **“ในระยะเวลาที่เท่ากัน ไก่ที่ได้กินเพียงแค่ข้าวขาวจะป่วย ในขณะที่ไก่ที่ได้กินเพียงแค่ข้าวซ้อมมือจะมีสุขภาพแข็งแรง”**

นายอาทิตย์จึงเริ่มต้นทำการทดลองเพื่อตรวจสอบว่าไก่ที่กินเพียงแค่ข้าวขาวจะป่วย ในขณะที่ไก่ที่ได้กินเพียงแค่ข้าวซ้อมมือจะสุขภาพแข็งแรง โดยกำหนดให้ ③ **“ไก่ในฟาร์มของเขา จะได้รับอาหารจากมนุษย์เท่านั้น ไม่ให้หากินเองตามธรรมชาติ”** หลังจากการทดลองนายอาทิตย์ค้นพบว่า ④

“ข้าวซ้อมมืออุดมไปด้วยวิตามิน ซึ่งช่วยป้องกันและบรรเทาโรคภัยมากมาย”

ซึ่งสามารถสนับสนุนความคิดของเขา

	สมมติฐาน (Hypothesis)	ข้อตกลงเบื้องต้น (Assumption)	ข้อสรุป (Conclusion)	การพยากรณ์ (Prediction)	คำถามการวิจัย (Inquiry question)	ฉันไม่รู้
ข้อความที่ ①	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ②	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ③	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ④	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ

คำถามท้าย

นายภูผาเป็นนักวิทยาศาสาสตร์ ซึ่งกำลังทำงานวิจัยเกี่ยวกับกาเซลล์ (สัตว์กีบคู่ขนาดเล็ก)ในบริเวณทุ่งหญ้าสะวันนา ณ ประเทศเคนย่า ในระหว่างที่เขากำลังศึกษาอยู่นั้น เขาสังเกตเห็นพฤติกรรมที่ผิดปกติของกาเซลล์ (Gazelle) นั่นคือ กาเซลล์ (Gazelle) มักจะกระโดดสูงเพื่อโชว์แถบสีขาวบริเวณสะโพก เมื่อกำลังถูกล่าด้วยเสือชีตาร์ นายภูผาจึงเกิดความสงสัยว่าเหตุใดกาเซลล์ (Gazelle) จึงมักจะแสดงพฤติกรรมนี้ ดังนั้นเขาพึงพยามคิดหาเหตุผลที่เป็นไปได้จากงานวิจัยที่ผ่านมาและจากความรู้ของเขา

จากข้อสงสัยที่เกิดขึ้นนั้น นายภูผาจึงเกิดความคิดขึ้นว่า ① **“การที่กาเซลล์ (Gazelle)มีพฤติกรรมกระโดดสูง เพราะว่ามันต้องการที่จะปกป้องลูกจากเสือชีตาร์”** ซึ่งถ้าสิ่งที่เขาคิดถูกต้อง ② **“เมื่อเสือชีตาร์ปรากฏตัว กาเซลล์ (Gazelle) ตัวที่มีลูกจะกระโดดสูง ส่วนกาเซลล์(Gazelle) ตัวที่ไม่มีลูกจะโดไม่สูง”** แต่อย่างไรก็ตาม มันไม่มีความแตกต่างอย่างชัดเจนของจำนวนกาเซลล์ (Gazelle) ระหว่างตัวที่มีลูกและกระโดดสูง กับตัวที่ไม่มีลูกและกระโดดไม่สูง ซึ่งจากข้อมูลนี้ นายภูผาจึงพบว่า ③ **“การปรากฏตัวของเสือตาร์ ไม่ส่งผลต่อความแตกต่างของระดับการกระโดดสูงของกาเซลล์ (Gazelle) ที่มีลูกและไม่มีลูก”** ดังนั้นนายภูผาจึงเกิดความคิดใหม่ว่า ④ **“ การกระโดดสูงเป็นการแสดงถึงความสามารถ เพื่อแสดงว่าเป็นการยากที่จะล่าได้สำเร็จ”** ถ้าสิ่งที่เขาคิดถูกต้องแล้ว ⑤ **“เสือชีตาร์จะล่าหรือโจมตีกาเซลล์ (Gazelle) ตัวที่กระโดต่ำ มากกว่าตัวที่กระโดดสูง”** หลังจากเฝ้าสังเกตและจดบันทึกข้อมูล แสดงให้เห็นว่ากาเซลล์ (Gazelle)ตัวที่กระโดดต่ำถูกล่ามากกว่ากาเซลล์ (Gazelle) ตัวที่กระโดดสูงจริง ๆ จากการข้อมูลนี้ ทำให้นายภูผาตัดสินใจได้ว่า ⑥ **“การที่กาเซลล์ (Gazelle) กระโดดสูงเพื่อที่จะแสดงความสามารถให้เสือชีตาร์เห็นว่าจะล่าหรือโจมตีมันได้ยาก”**

	สมมติฐาน (Hypothesis)	ข้อตกลงเบื้องต้น (Assumption)	ข้อสรุป (Conclusion)	การพยากรณ์ (Prediction)	คำถามการวิจัย (Inquiry question)	ฉันไม่รู้
ข้อความที่ ①	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ②	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ③	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ④	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ⑤	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
ข้อความที่ ⑥	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ

ตอนที่ 6 ความสามารถในการสร้างสมมติฐานทางวิทยาศาสตร์

คำชี้แจง จงอ่านข้อความข้างล่าง และตอบคำถามดังต่อไปนี้

สถานการณ์ที่เกี่ยวข้องกับวิธีการทางวิท

พิธีไหว้ครูถูกกำหนดให้มีขึ้นในวันพฤหัสบดีของเดือนมิถุนายน
จัดขึ้นเพื่อแสดงถึงความระลึกถึงพระคุณของครู
ดอกเข็มเป็นหนึ่งในดอกไม้ที่ใช้ในพิธีไหว้ครู
เนื่องจากดอกเข็มนั้นมีปลายแหลม
จึงถือเป็นสัญลักษณ์ของการมีสติปัญญาที่เฉียบแหลม
ดังนั้นในช่วงเย็นของวันพุธ
นักเรียนจะต้องเตรียมจัดพานไหว้ครูเพื่อใช้ในวันรุ่งขึ้น
พรุ่งนี้แก้วมีนัดกับเพื่อนๆ เพื่อจัดพานสำหรับไหว้ครู
ดังนั้นแก้วจึงออกไปเก็บดอกเข็มบริเวณหน้าบ้านเพื่อนำไปสมทบกับเพื่อน ๆ
ในระหว่างที่กำลังเก็บดอกเข็มนั้น
แก้วสังเกตเห็นว่าต้นดอกเข็มที่บ้านของเธอนั้น ออกดอกมากมาย
แต่ในขณะที่ต้นดอกเข็มที่โรงเรียนแทบจะไม่ออกดอกเลย

คำถามที่แก้วสร้างขึ้น

※ ทำไมต้นดอกเข็มที่บ้านของฉันจึงออกดอกมากกว่าต้นดอกเข็มที่โรงเรียน?

1) จงตั้งสมมติฐานทางวิทยาศาสตร์จากคำถามของแก้ว

2) จงเขียนสิ่งที่นักเรียนเคยรู้ (ความรู้, ประสบการณ์ ฯลฯ)
เกี่ยวกับสถาการณ์นี้ ที่นักเรียนใช้ในการตั้งสมมติฐาน

국문 초록

본 연구의 목적은 태국 7 학년 학생들의 과학적 가설 수립 능력 및 인식을 조사하는 것이다. 3 개 태국 공립학교, 총 285 명의 태국 7 학년 학생들을 대상으로 가설 수립 능력 및 인식에 대한 설문조사를 실시하였다. (태국어)

‘과학적 지식의 본성’ 과 ‘과학적 방법’에 대한 태국 7 학년 학생들의 인식을 조사한 결과는 다음과 같다. 첫째, 학생들은 과학적 지식이 분명한 근거를 바탕으로 창조되고 불완전하며 가변적이 라는 것을 인식하고 있었다. 그러나, 그들은 과학적 지식이 과학자에 의해 창조되는 것이 아니라, 발견되는 것이라고 생각하고 있었다. 둘째, 대부분의 학생들은 과학적 방법이 곧 ‘가설’, ‘예측’, 그리고 ‘결론’ 이라고 들어왔으며, 오직 절반의 학생들만이 ‘가정’을 알고 있었다. 또한 그들은 ‘가정’을 제외한 모든 과학적 방법 용어들을 잘 이해한다고 생각하고 있었고 학생들은 많은 경우에 ‘예측’과 ‘가설’을 구분하지 못했다.

태국 7 학년 학생들의 과학적 가설에 대한 인식을 조사한 결과를 보면, 학생들은 가설을 분명한 근거를 바탕으로 수립되고 확인되어야

하며 검증 할 수 있는 진술로서 불완전하고 가변적인 것으로 알고 있었다. 그리고 그들은 가설이 독립 변인와 종속 변인의 관계로써 기술된다는 것을 모르고 있었다.

마지막으로, 태국 7 학년 학생들의 과학적 가설을 수립 능력에 대한 조사 결과에 따르면, 학생들은 문제 제기에 대한 해답으로서 가설을 수립하는 능력, 그리고 오직 독립변인으로만 표현되는 가설을 수립하는 능력을 갖고 있었다. 더욱이 그들은 검증 가능한 가설을 수립할 수 있었다. 또한 학생들은 그들이 가설을 수립하는 데 사용한 분명한 근거를 제시할 수 있었다. 그러나 그들은 일반화된 가설을 수립하는 능력이 부족하였다. 그러므로 태국 7 학년 학생들은 가설을 이해하고는 있지만 가설을 잘 수립하지는 못한다고 말할 수 있다.

본 연구의 결과로, 태국 7 학년 학생들은 변인 추출 과정에 대한 더 많은 연습이 필요하다고 결론지을 수 있다. 특히, 학생들의 가설 수립 기술을 향상시키기 위한 새로운 교육 방법이 필요하다.

주요어 : 과학의 본성, 과학적 방법, 과학 탐구 과정 요소, 실험, 가설, 예측, 태국 중학생, 인식

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