THE METACOGNITIVE STRATEGY EMBEDDED IN INQUIRY LEARNING MODEL TO ENHANCE SCIENCE COMPETENCIES, SCIENCE PROCESS SKILLS, AND SELF-EFFICACY IN SCIENCE OF SEVENTH GRADE STUDENTS

DISSERTATION

BY

BENYAPA PRACHANANT

Presented in Partial Fulfillment of the Requirement for the

Doctor of Education Degree in Science Education

at Srinakharinwirot University

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AN ABSTRACT

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Benyapa Prachanant. (2018). *The Metacognitive Strategy Embedded in Inquiry Learning Model to Enhance Science Competencies, Science Process Skills and Self-efficacy in Science of Seventh Grade Students*. Dissertation, Ed.D. (Science Education). Bangkok: Graduate School, Srinakharinwirot University. Advisor Committee: Assoc. Prof. Dr. Parin Chaivisuthangkura, Dr. Pinit Khumwong, Dr. Wanida Tanaprayothsak, Dr. Supika Vanitchung.

This research had four objectives; 1) to identify science classroom problems by exploration of teachers' perception, the data were collected from 36 science teachers selected by stratified random sampling and simple random sampling using an opened-questionnaire and then analyzed by content analysis. The results revealed that the students lacked science process skills and had less concerned about their learning. Additionally, to explore lower secondary school students' level of science process skills, the data were collected by using a science process skills test obtained from 426 students in Bangkok using stratified random sampling and simple random sampling. The results revealed that level of science process skills among the students were at a overall level of moderate and that certain integrated science process skills were at low level; 2) in order to develop the metacognitive strategy embedded in inquiry learning model, which consisted of five phases; engagement-planning (P)-monitoring (M)-evaluating (E), exploration-P-M-E, explanation-P-M-E, elaboration-P-M-E, and evaluation; 3) to evaluate the effectiveness of a learning model on the science process skills, science competencies, and self-efficacy in science and 4) to find the correlation between the science competencies of students, science process skills, and self-efficacy in science. The participants consisted of a classroom of thirty-three seventh grade students selected by purposive sampling. The data were collected in the second semester of 2017 academic year on the topic of atmosphere and weather. The research instruments included a science process skills test, a science competencies test, and a self-efficacy in science. The results revealed the following: 1) students' posttest scores of the students on science process skills were not significantly higher than the pretest scores at .05 level; 2) students' posttest scores of the overall science competencies were significantly higher than the pretest score at .05 level; 3) Students' posttest score of self-efficacy in science was significantly higher than the pretest score at .05 level and 4) Students' science competencies had high correlation with science process skills ($r = .704$) and students' science competencies had no correlation with self-efficacy in science ($r_s = .004$).

รูปแบบการเรียนรู้แบบสืบเสาะหาความรู้โดยกลวิธีทางอภิปัญญา เพื่อส่งเสริมสมรรถนะทางวิทยาศาสตร์ ทักษะกระบวนการทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนชั้นมัธยมศึกษาปีที่ 1

บทคัดย่อ

ของ

เบญญาภา ประชานันท์

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา
ตามหลักสูตรปริญญาการศึกษาดุษฎีบัณฑิต สาขาวิชาวิทยาศาสตรศึกษา
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งานวิจัยนี้มีความมุ่งหมาย 4 ประการ ได้แก่ 1) ศึกษาสภาพปัญหาที่มักพบในห้องเรียนวิทยาศาสตร์ โดยใช้การตอบแบบสอบถามของครูวิทยาศาสตร์ จำนวน 36 คน ซึ่งเป็นกลุ่มตัวอย่างที่ได้มาจากการสุ่มตัวอย่างแบบแบ่งชั้นภูมิและสุ่มอย่างง่ายตามลำดับ ผลการวิเคราะห์เนื้อหาจากแบบสอบถามพบว่า นักเรียนขาดทักษะกระบวนการทางวิทยาศาสตร์และยังขาดความตระหนักรู้ การรับรู้สิ่งที่ทำในระหว่างการเรียนรู้ นอกจากนี้จากการสำรวจระดับทักษะกระบวนการของนักเรียนชั้นมัธยมศึกษาตอนต้นในเขตกรุงเทพมหานคร จำนวน 426 คน ซึ่งเป็นกลุ่มตัวอย่างที่ได้มาจากการสุ่มตัวอย่างแบบแบ่งชั้นภูมิและสุ่มอย่างง่ายตามลำดับ ผลการสำรวจพบว่า นักเรียนมีทักษะกระบวนการทางวิทยาศาสตร์ขั้นพื้นฐานในระดับปานกลางและมีทักษะกระบวนการทางวิทยาศาสตร์ขั้นบูรณาการในระดับต่ำ 2) พัฒนารูปแบบการเรียนรู้แบบสืบเสาะหาความรู้โดยกลวิธีทางอภิปัญญา ซึ่งประกอบด้วย 5 ขั้นตอน คือ 1) ขั้นสร้างความสนใจ-วางแผนตรวจสอบประเมิน 2) ขั้นสำรวจค้นหา-วางแผนตรวจสอบประเมิน 3) ขั้นอธิบาย-วางแผนตรวจสอบประเมิน 4) ขั้นขยายความรู้-วางแผนตรวจสอบประเมิน 5) ขั้นประเมินผล 3) ศึกษาประสิทธิภาพของรูปแบบการเรียนรู้ที่มีต่อสมรรถนะทางวิทยาศาสตร์ ทักษะกระบวนการทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนชั้นมัธยมศึกษาปีที่ 1 และ 4) ศึกษาความสัมพันธ์ของทักษะกระบวนการทางวิทยาศาสตร์ สมรรถนะทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ โดยกลุ่มที่ศึกษาเป็นนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1 จำนวน 1 ห้องเรียน 33 คน ดำเนินการศึกษาในภาคเรียนที่ 2 ของปีการศึกษา 2560 เนื้อหาบรรยากาศและลมฟ้าอากาศ เครื่องมือวิจัยประกอบด้วย แบบวัดทักษะกระบวนการทางวิทยาศาสตร์ แบบวัดสมรรถนะทางวิทยาศาสตร์ และแบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์ ผลการศึกษาพบว่า 1) คะแนนเฉลี่ยทักษะกระบวนการทางวิทยาศาสตร์ของนักเรียนหลังเรียนไม่สูงขึ้นจากก่อนเรียน อย่างมีนัยสำคัญทางสถิติที่ระดับ .05 2) คะแนนเฉลี่ยคะแนนเฉลี่ยสมรรถนะทางวิทยาศาสตร์ของนักเรียนสูงขึ้นอย่างมีนัยสำคัญทางสถิติที่ระดับ .05 3) คะแนนเฉลี่ยการรับรู้ความสามารถทางวิทยาศาสตร์ของนักเรียนสูงขึ้นอย่างมีนัยสำคัญทางสถิติที่ระดับ .05 และ 4) ทักษะกระบวนการทางวิทยาศาสตร์มีความสัมพันธ์ระดับสูงกับสมรรถนะทางวิทยาศาสตร์ (r = .704) สมรรถนะทางวิทยาศาสตร์ไม่มีความสัมพันธ์กับการรับรู้ความสามารถทางวิทยาศาสตร์ของนักเรียน (r_s = .004)

The dissertation titled

"The Metacognitive Strategy Embedded in Inquiry Learning Model to Enhance Science Competencies, Science Process Skills, and Self-efficacy in Science of Seventh Grade Students"

by

Benyapa Prachanant

has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Education degree in Science Education of Srinakharinwirot University

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Benyapa Prachanant

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CHAPTER 1
INTRODUCTION

Background

In rapidly changing world, knowledge of science and technology is significant to the development of a country both economically and socially. Moreover it is related to everyone's daily life (OECD. 2007; The International Science, Mathematics and Technology Education Conference: ISMTEC. 2013: 1).The research indicated that knowledge and skills that are connected to the real lives of people in society could have predictable effects in the economic development (PISA Thailand. 2007: 1). The situations, problems, and issues that individuals encounter in their daily lives requires some understanding of science and technology (OECD. 2007). Science enables us to acquire essential investigative skills to seek knowledge, develop various thinking skills, and allow for the abilities of systematic problem-solving and verifiable decision-making based on diverse data and evidence to flourish. Consequently, science is essential to the modern world (The Ministry of Education. 2008: 106).

It is necessary to develop students' science process skills in order to prepare themselves for their lives in the future. The OECD Program for International Student Assessment (PISA) which assesses the abilities of 15-year-old students in terms of knowledge and skills which are essential for full participation in society. As such it focuses on student competence in the key subject areas of reading, mathematics, and science. Especially in 2006, PISA was focusing on science literacy, which measures the ability to complete tasks relating to real life, by applying their understanding of scientific concepts to the real world (OECD. 2007: 16-20). Science literacy was assessed through the following science competencies: identifying scientific issues, explaining phenomena scientifically, and using scientific evidence (OECD. 2007:35). They had placed emphasis on knowledge about science as an aspect of science performance, which relates to an enquiry in PISA 2006 about scientific process. Moreover, it measured students' science competencies which were used to test the students' connection to key cognitive abilities such as inductive/deductive reasoning, system-based thinking, critical decision making,

transformation of information (creating tables or graphs out of raw data), construction and communication of arguments and explanation based on data, thinking in terms of models, and the use of science (OECD. 2007: 36).

PISA has measured cognitive ability in terms of a yield-study, assessing life-skills and broad areas of literacy rather than curriculum domains. They also measured non-cognitive outcomes as PISA believes that success in school and in life—depends on being committed, sharing values and beliefs, respecting and understanding others, motivation to learn and to collaborate, and being able to regulate one's own learning behavior.

It had been shown that beliefs and attitude are positively correlated with students' performance in the field of science (OECD. 2007). This relationship was reciprocal as science-related beliefs and attitudes could be a consequence of higher science performance, as well as causing higher science performance. A positive self-concept and self-efficacy (or science-related beliefs) were highly correlated to motivation, learning behavior, general expectations for the future, and students' performance (OECD. 2007). It was consistent with the studies of Bandura (1994), Zimmerman (2000), Bong & Skaalvik (2003), and Shari & Pajares (2006) indicating that self-efficacy is an effective predictor of motivation, performance, and achievement.

The Self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance (Bandura. 1994:2; 2006: 309). Meaning that it could refer to individual's effort and persistence to execute the tasks. Therefore, knowing a student's self-efficacy would help predict student's learning or even potentially the student's pathways. It is a key impact to motivation; a strong sense of self-efficacy can affect students' willingness to take on challenging tasks and also refer to how much effort the students give and how persistent they are (Bandura. 1994: 2). The most influential part to building up self-efficacy is a student's performance accomplishments, which are based on personal mastery experience. Consequently, the relationship between student's self-efficacy and student performance may well be reciprocal; with students with higher academic ability being more confident and a higher level of confidence (OECD. 2007: 134).

The PISA 2006 included the measurement of self-efficacy in science which refers to students' belief in their own ability to handle tasks effectively and difficulties in the student

questionnaire. That measurement was focused on students' efficacy in applying science to daily life. Finding, that while Thai students' science performance is low, their self-efficacy seemed high. It was 0.078 of standardized self-efficacies, meaning the score was stronger than the OECD average mean score (OECD. 2007: 136). In other hand, Thai students' science self-efficacy was weakly correlated with the students' motivation.

The results of this phenomenon have been found to be the result of an overestimation. Bandura states that some overestimation of capability is useful, as it increases effort and persistence (Bandura. 1986 cited in Pajares. 1996: 339). Moreover, Pajares (1996) suggests that students should improve their skill to make the calibration more accurate rather than to try and lower the students' efficacy perception, or discourage their overconfidence. Consequently, it would be good to improve students' science competencies (science literacy) to make it a higher score and have more consistency with the Thai students' self-efficacy in science.

Science process skills are crucial to science literacy in order to be a scientifically literate person (Seetee. 2016). The second time the PISA focused on science literacy was in the PISA 2015, which further illustrated that science process skills is important for science literacy in terms of procedural knowledge. It acquired scientific knowledge through the skills of enquiry and problem solving in real life. Moreover, science competency is measured in terms of explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically (OECD. 2013: 7). Therefore, science process skills might be a key to attaining those competencies.

However, 36 teachers have mentioned problems in science classroom. It reveals that a total of 35.89% of teachers state that students are lacking in the areas of science process skills and awareness while learning. Such problems had been found in the past. Some problems were found in science process skills in that both students and student teachers were lacking. An example of this was when Padilla, Cronin, and Twiest (1985) surveyed the basic process skills of 700 middle school students with no special process skill training. They found that only 10% of the students scored above 90% correct, even at the eighth-grade level (Padilla. 1990). In grades nine and ten, students who indicated that their integrated science process skills mean score was low and unsatisfactory were

especially weak in interpreting data, recording data, generalizing, formulating hypotheses and identifying variables (Yvonne; & Kola. 2001).

Likewise, a study on former students in Johor Bahru, Indonesia showed that most of the participants' knowledge of the scientific process was unsatisfactory. (Aina. 2006 cited in Surif; Ibrahim; & Mokhtar. 2012: 419). Furthermore, the studied problem-solving approach in a laboratory has found that students performed poorly in procedural knowledge (Wilson. 1987 cited in Surif; Ibrahim; & Mokhtar. 2012). Some reports showed that students performed poorly in the process of planning for strategies and implementing correct strategies even though they did not encounter any difficulty in understanding the problem (Zuraidi. 1999 cited in Surif; Ibrahim; & Mokhtar. 2012).

In the Thai educational system, we have found problems related to students' science process skills throughout in-service and pre-service science teachers. The most mentioned problem is the lack of students being able to infer and interpret data which leads to students not being good at drawing conclusions (Chaiyen; Bunsawansong ;& Yutakom. 2007; Kaewseehabut ;& Khantho. 2007; Nakthong; Anuntasethakul ;& Yutakom. 2007; Chairam; Klahan ;& Coll. 2015). They are incapable of presenting the connection between the claim and evidence (Chairam; Klahan ;& Coll. 2015. Somsuk. 2015) and they almost need some help from a teacher (Chairam; Klahan ;& Coll. 2015). The survey also found that the inferring skill of in-service and pre-service science teachers was the weakest of the skills (13 skills). The mean score was 50% and 35% of in-service and pre-service science teachers respectively. They just observed without inferring data (Kruea-In; & Fakcharoenphol. 2015). Moreover, high school students still are weak in basic science process skills such as students not being able design a table to record the data, but they can draw the graph they they used to practice (Chairam; Klahan ;& Coll. 2015). Grade six students are lacking in measuring skills; they make improper use of tools or equipment that is required as well as make errors, including the improper use of measurement unit (Kaewseehabut ;& Khantho. 2007). It was also found that grade 10th students lack of skill in using numbers is highest among other skills (Nakthong; Anuntasethakul;& Yutakom. 2007). It has been found that much of science process skills are lacking integration in high school students, in Thailand namely, as they are confused between the independent and dependent variables in

experiments (Kaewseehabut ;& Khantho. 2007; Chairam; Klahan ;& Coll. 2015) while the study of Nakthong et al (2007) found that students can identify the control variable better than other variables, Somsuk (2015) found that lacking of the ability to identify and control variables as a skill is an obstacle to the learning activities of the 2I3C physics instructional model using scientific argumentation. Furthermore, some studies have found students lacking in defining operationally (Chaiyen; Bunsawansong ;& Yutakom. 2007; Nakthong; Anuntasethakul;& Yutakom. 2007), formulating hypotheses(Nakthong; Anuntasethakul;& Yutakom. 2007), and experimenting skills(Chaiyen; Bunsawansong ;& Yutakom. 2007) including not being able to explain the procedures of the experiments clearly (Nakthong; Anuntasethakul;& Yutakom. 2007). It seems that Thai students are weak with both basic and integrated science process skills, which need to be required to investigate the natural world. Students' science process skills need to be improved since they are at lower levels because the lack of science process skills might impact their understanding or even restrain them from acquiring science knowledge effectively while learning science, especially via doing experiments or inquiry.

Consequently, students should know how to start, what the steps of the procedure are, what the purpose is, and how to find the answers. In other words, students should have strength on process skills for exploring the natural world. By addressing these problems, the researcher aims to develop the learning model which could improve students' science process skills, their self–efficacy in science, including using the model for practicing the following science competencies: explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically. This would be beneficial in attempting to prepare the students to be scientifically literate people, and using it when encountered in their real life.

By reviewing the literature, it showed that learning based on inquiry has been used for improving students' science process skills (Şimşek; & KabapÕnar. 2010; Koksala; & Berberoglu. 2012; Lati; Supasorn; Promarak. 2012; Yadav; & Mishra. 2013; Aydoğdua; Buldur; & Kartal. 2013; Ogan-Bekiroğlu; & Arslan. 2014; Chairam; Klahan;& Coll. 2015). Some studies are used by the 5E learning model with elicitation strategy (Rompayom. 2010) and some are used by laboratories based on the 7E learning cycle (Yadav; & Mishra. 2013).

However, the results of teachers' opinion have identified that Thai students not only lack science process skills, but they also do not have a working plan, do wrong procedures, and cannot reflect the purpose of an experiment (see Chapter 4). This demonstrates that students need more plans and need to set the goal of the experiment or task through the goal of each procedure. They also need to monitor it during a procedure to ensure that students are concentrated on the path of the procedure.

Therefore, it should be fulfilled with the strategy in order to keep the students' attention, reflect the students' understanding on each step of procedure, and also maintain control while they are doing the experiments. By reviewing the literature, this researcher has found studies related to metacognition that can improve students' science process skills (Saribas; & Bayram. 2009; Mollozzi; & Heilbronner. 2013). Schraw and Dennison (1994) define the metacognition as the ability to reflect on understanding and control's one learning. There are two main subcomponents of metacognition; knowledge of cognition and regulation of cognition. Researcher has considered and hypothesized in the regulation of cognition as it is a set of activities that would help students to control their learning. Regulation of cognition is referred to 1) planning—setting goal, managing all resources, and maintaining prior knowledge 2) monitoring—online awareness of comprehension, task performance, and testing by themselves while learning 3) evaluating—appraising the regulatory processes and products (Schraw. 1998; Schraw et al.1995; Schraw et al. 2006). Moreover, Schraw et al (2006) recommend that metacognition enables individuals to monitor their current knowledge, skills, and plan learning resources. If students understand how to use regulatory skills in the classroom, their learning will be improved (Cross; & Paris. 1988; King. 1991 cited in Schraw. 1998; Schraw; & Dennison. 1994: 466). Consequently, the response to problems about the regulation of cognition are addressed in the survey.

According to the literature review above, to solve these problems, inquiry learning is considered the main approach that drives on the 5E learning model: 5E inquiry. The Institute for the Promotion of Teaching Science and Technology (IPST) has supported and made up workshops of 5E for science teachers (IPST (Biology). 2006) which leads to Thai science teachers being familiar with the 5E learning model (Science Institute. 2013 cited in Chamrat. 2013: 8). Consequently, researcher selected the 5E inquiry learning model and infused it

with metacognition in terms of the regulation of cognition (planning, monitoring, and evaluating) in four phases of 5E. These four phases are the engagement, exploration, explanation, and elaboration phases. Finally, the learning model consists of five phases; engagement-planning (P)-monitoring (M)-evaluating (E),exploration-P-M-E, explanation-P-M-E, elaboration-P-M-E, and evaluation. This study emphasizes attempts for students to develop the key science competencies: explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. Based on the PISA 2015 framework, the contents of which are appropriate to these purposes, should be relevant to real-life situations which may relate to personal, local, national and global situations, and can represent an important scientific concept or major explanatory theory that has enduring utility (OECD. 2013: 17). Therefore the metacognitive strategy embedded in this learning model's inquiry learning model is based on the topic of the atmosphere and weather because it consists of many fields of science such as biology, chemistry, physic, geology, and oceanography that must be understood and integrated. It is one of the most relevant science subjects that applies to students' everyday lives and students' concern on environmental issues such as acid rain, destruction the ozone layer, and ground-water pollution as suggested by NSES (Mao; & Chang. 1999: 94). It was suited to the objective science literacy (measure through science competencies test) to know and enhance students to integrate both knowledge of science and skills to solve problems in daily lives.

Data were collected on seventh grade students in Bangkok, Thailand that had problems in science classes as mentioned in preparation stage.

Objectives of the study

1. To discover the problems based on science classroom in Thailand.
2. To develop the metacognitive strategy embedded in inquiry learning model.
3. To evaluate the effectiveness of a learning model on students' science process skills, science competencies, and self-efficacy in science.
4. To find the correlation between students' science competencies and science process skills.

5. To find the correlation between students' science competencies and self-efficacy in science.

Significance of the Study

According to the results of survey in the preparing stage, it is indicated that students' lack of science process skills, which is the core skills in learning science, and that students are less aware while learning; cannot do what they need to do and therefore cannot reflect on the purposes of experiment. This study aims to develop the model of metacognition strategy embedded in learning inquiry in order to enhance students' science process skills, science competencies, and self-efficacy in science. The learning model would make the students more aware of the procedure, provide students improved science processing skills, which are important in preparing students for their daily lives in the future (science competencies). Provide the teacher with the knowledge to improve students' motivation in the path of science, through science self-efficacy by adjusting the level of students' self-efficacy in science to be more consistent with their performance; effectively predictable motivation. Finally, the model of metacognition strategy embedded in the learning inquiry would be a choice of teaching instructions for science teachers and the policy makers to implement in science education.

Research question

1. What problems are often found in the science classroom in Thailand?
2. What are the features of metacognitive strategy embedded in inquiry learning model?
3. Does the metacognitive strategy embedded in inquiry learning model effect on students' science process skills, science competencies, and self-efficacy in science?
4. Do the students' science competencies have correlation with science process skills?
5. Do the students' science competencies have correlation with self-efficacy in science?

Scope of the Study

This studies research and development consisted of three stages to study. Those stages included the population and participants as following;

1. Preparation Stage: Basic data

1.1 Teachers' opinion related to science classroom problems

The population included science teachers who taught grade eight students in public schools all over Thailand.

The participants were 36 science teachers who taught grade eight students and were willing to respond to the given question from 36 schools located in nine areas based on PISA Thailand criteria of sampling. Four science teachers were selected from each area. They were selected by a stratified random sampling and simple random sampling, respectively.

1.2 An exploration of students' level of science process skills

The population included lower secondary school students in Bangkok was 230,101 students which were consisted of 116,526 boys and 113,575 girls in the 2017 academic year.

The participants were 426 students who were lower secondary school students in Bangkok during the 2017 academic year. They were selected by using 5% of the Yamane formula, stratified random sampling and simple random sampling, respectively.

2. Development of Learning Model Stage:

The pilot study was conducted during November – December 2017 at a School in Bangkok during the second semester of the 2017 academic year. All processes of teaching were conducted by researcher. Two classrooms of 1/8 (42 students) and 1/9 (28 students) with total 70 students; one class was high-moderate achievers and emphasizing on science (English program) and one class was moderate-low achiever emphasizing on musical program.

3. The Evaluating Learning Model Stage:

The population included seventh grade students in Bangkok in the second semester of the 2017 academic year.

. The participants consisted of thirty-three seventh grade students from a school in Bangkok in the second semester of the 2017 academic year. Purposive sampling was used; the sample was composed of students in public school, mixed achievers, that had problems in science classes, same as the results of teachers' opinions in preparation stage.

Additionally, this study verified the processes and was allowed to conduct the research from the Strategic Wisdom and Research Institute, Srinakharinwirot University which was approved in the certificate of approval referring to certificate number SWUEC/E-258/2560.

Contents:

Atmosphere and weather consisted of these topics: atmosphere, the effect of sun rays to atmosphere and air temperature, the effect of temperature to air density and air pressure, wind, humidity, cloud and precipitation, thunderstorm and tropical storm, weather forecast, and climate change El nino, La nina, greenhouse effect, global warming and air-pollution

Variables of the study:

1. Independent variable

Using of metacognitive strategy embedded in inquiry learning model

2. Dependent variable

-Students' science process skills

-Students' science competencies

-Students' self-efficacy in science

Definition of terms

1. **The metacognitive strategy embedded in inquiry learning model**

Referred to the new learning model which consists of five phases and emphasizing on students ability to plan, monitor, and evaluate in procedure of learning

inquiry which increases students' concerns on processes as well as accomplish the five features of inquiry. By details of five phases were:

1.1 Engagement-P-M-E phase: students were able to make a plan, monitor, and evaluate their abilities and prior knowledge. Therefore, students needed to be asked and evaluated their prior knowledge while discussing their ideas with friends, making plans, and responding to given learning activities, questions as well as teachers promoting students' interested in science questions and students being engaged in scientifically oriented questions to formulate a science question (testable question).

The procedures in this phase were: students were engaged by instructional material such as pictures, clip video, news, phenomena, and events that could be connected with the new science concept they would learn. Students used and evaluated prior knowledge related to those instructional materials. Students interested in issues related to the given instructional materials, proposed questions and discussed what they were curious about in those situations, and considered resources or time and reached the main question to explore. In term of experiment activity, that main question was planned and changed to become a testable question. Students asked themselves "what I know," and "what I do not know," because they are key when formulating the testable question. Checking the question by a checklist of testable question components and clarify via whole class discussion. Based on the discussion, students evaluated and fulfilled the final testable question.

1.2 Exploration-P-M-E phase: this phase aimed to enhance students abilities to make a plan, monitor, and evaluate their procedures to attain the required evidence. Students perceived their capabilities whilst making a plan and exploring. Therefore, students needed to be asked and evaluated on their knowledge and skills while discussing their ideas with friends, making a plan, and responding to given learning activities as well as students giving priority to evidence in responding to question.

The procedures in this phase were: Students set the main question/testable question as a goal to find out the answers. Students identify the needed evidence/data and propose the ways to get the evidence/data based on students' experience with everyday language. They then discussed and completed the writing plan in order to get the evidence before doing the experiment/exploration. Using the ISN notebook as the writing plan and recording

data sheet when doing the experiments. Students transferred the experiment plan in ISN notebook from everyday language (on left side) into science terminology (on right side); hypothesis, variables, and defining operationally variable. Continually checking the consistency among the plan, goal, and procedure while doing the experiment/exploration/task via a checklist. Afterwards they would discuss the results/data. Students then evaluated the evidence and all the results, inferring evidence/data, and any mistakes.

1.3 Explanation-P-M-E phase: this phase enhanced students ability to make a plan, monitor, and evaluate their scientific explanation. Students perceived their abilities in formulating the explanation from evidence, connecting the explanation to scientific knowledge, and communicating and justifying the explanations. Therefore, students needed to be asked and evaluated on their knowledge while discussing their ideas with friends, making a plan, and responding to given learning activities.

The procedures in this phase were: students would give priority to the explanation that was based on the evidence. Students connected the evidence or phenomena to science knowledge that they had learned or had gained as new knowledge. They would discuss and interpret the data or experiment results. Plans to make conclusions and scientific explanations were started by recalling the goals and evidence required. Students were taught to ask themselves “what I know,” and “what I need to know,” to be the key when formulating the scientific explanation. Students made a conclusion and scientific explanation by using an explanation template/guidance. Students checked the explanation via the checklist and during class discussion. They evaluated and made decisions to fulfill the explanation.

1.4 Elaboration-P-M-E phase: this phase aimed to enhance students ability to make a plan, monitor, and evaluate the application of knowledge and skills they had learned to solve the problems or science tasks, criticize news, experiment, explain scientific phenomena, and so on. Students perceived their own abilities in both knowledge and skills including the realization about the fruitfulness of scientific contribution. Therefore, students needed to be asked and evaluated about their knowledge and skills while discussing their ideas with friends, responding to the science task, such as formulating testable

questions/goals, exploring the evidence and formulating the explanation based on evidence, connecting explanation to scientific knowledge including communicating, and justifying the explanation.

The procedures in this phase were: students applied science knowledge and skills that they had learned; set the goal of assigned science task, make all the plans to attain a testable question, data/evidence, and using scientific knowledge to explain phenomena or other situations scientifically.

1.5 Evaluation phase: this phase aimed to evaluate students' knowledge and skills. Students perceived their own abilities in both knowledge and the processes as students respond to the questions, worksheet and a self-evaluation form about their gained knowledge and skills. In other words, students perceived their capabilities related to learning concept and learning ability they experienced which affects their level of self-efficacy in science.

The procedures in this phase were: students measured all knowledge and skills they had learned through the questions, worksheet, journal, and self-evaluation form in terms of what they had learned by comparing knowledge and skills between pre- and post- learning activity.

2. Science process skills

Referred to students' abilities to use 13 process skills for doing the experiments, investigating natural world (knowledge), and thinking about problems tomake a decision. Itwas consisted of two groups of skills;

2.1 Basic science process skills:there are 8 skills namely;1.1 observing; 1.2 classifying;1.3 measuring ; 1.4 using space/time relationship; 1.5 using number ; 1.6 communicating ; 1.7 predicting ; 1.8 inferring

2.2 Integrated science process skills:there are 5 skills namely;2.1 defining operationally; 2.2 formulating hypotheses;2.3 interpreting data;2.4 identify and controlling variables; 2.5 experimenting

3. Science competencies

Science competencies are defined into 3 aspects, the same as the PISA 2015, and will be measured by the science competencies test which was constructed by the researcher. Those competencies were;

Competence 1: Explain phenomena scientifically

Recognize, offer and evaluate explanations for a range of natural and technological phenomena demonstrating the ability to: Recall and apply appropriate scientific knowledge; Identify, use and generate explanatory models and representations; Make and justify appropriate predictions; Offer an explanatory hypotheses; Explain the potential implications of scientific knowledge for society.

Competence 2: Evaluate and design scientific enquiry

Describe and appraise scientific investigations and propose ways of addressing questions scientifically by demonstrating the ability to: Identify the question explored in a given scientific study; Distinguish questions that are possible to investigate scientifically; Propose a way of exploring a given question scientifically; Evaluate ways of exploring a given question scientifically; Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations.

Competence 3: Interpret data and evidence scientifically

Analyze and evaluate scientific data, claims and arguments in a variety of representations and draw appropriate conclusions demonstrating the ability to: Transform data from one representation to another; Analyze and interpret data and draw appropriate conclusions; Identify the assumptions, evidence and reasoning in science-related texts; Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations; Evaluate scientific arguments and evidence from different sources (*e.g.* newspaper, internet, journals)

4. Self-efficacy in science

Referred to as students' perception of their capability to execute the tasks given to them, which are evaluated in terms of their level of students' confidence in four aspects. Students are presented with items portraying different levels of task demands and they rate the strength of their belief with a five point *scale (strongly disagree, disagree, neither, agree, strongly agree)*. The details of four aspects are as follow;

Aspect 1: explanations in science lesson they have learned (scientifically)

Referred to as the students' belief that relates their level of capabilities in making scientific explanations by using scientific principles that they have learnt to explain the phenomena through belief in their capabilities to connect content and resources to explain scientifically the phenomena.

Aspect 2: planning and designing experiment and working in science

Referred to students' belief of their level of capabilities in using science equipment and science process skills to propose and design the ways for exploration, and includes their belief on their ability to do science tasks successfully.

Aspect 3: applying science in daily life

Referred to students' belief in relation their level of capabilities in applying science knowledge in daily life, identify evidences/reasons scientifically include evaluate argument issues and evidences from any resources in daily life (news, article, social media etc.).

Aspect 4: presenting and communicating science lesson

Referred to students' belief in relation to their level of capability in analysis and interpreting scientific data in order to communicate it in terms of verbal, writing, discussion and explaining to others.

Conceptual framework of the study

The conceptual framework of the study was a metacognitive strategy embedded in inquiry learning model which was done by infusing between 5E inquiry and the metacognition in term of regulation of cognition (or metacognitive strategy). The regulation of cognition consisted of planning (P), monitoring (M), and evaluating (E) and these became the sub-step in the 5E phases model. These sub-steps were driving in four phases of 5E

model. The learning model included 5 phases; engagement-P-M-E, exploration-P-M-E, explanation-P-M-E, elaboration-P-M-E, and evaluation phase.

The using of metacognitive strategy embedded in inquiry learning model aimed to enhance students' science process skills, students' science competencies and their self-efficacy in science. The correlation between students' science process skills, students' science competencies and self-efficacy in science were calculated. The relationship between the learning model and dependent variables; science process skills, science competencies and self-efficacy in science were illustrated in Figure 1.

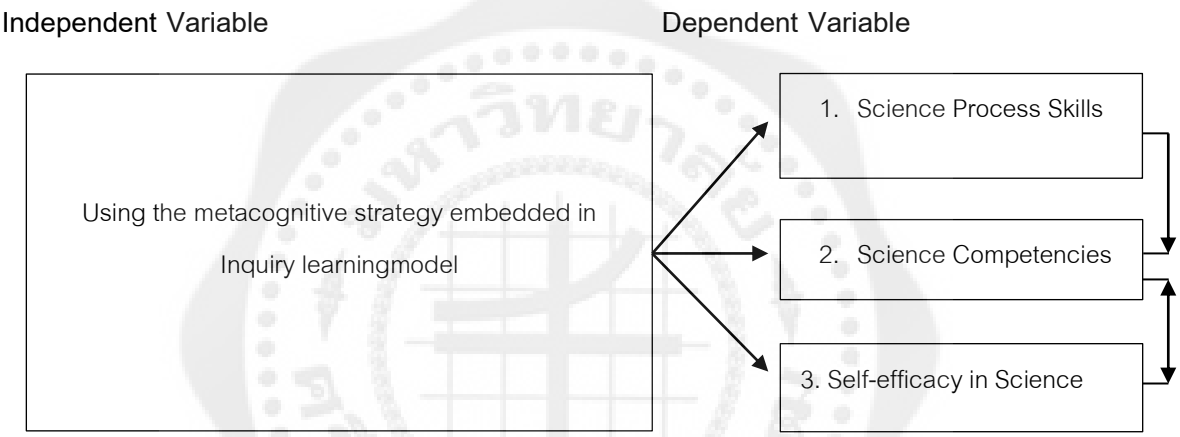

FIGURE 1 Conceptual framework of the study

Research hypotheses

The metacognitive strategy embedded in inquiry learning model will affect on students' science process skills, science competencies, and self-efficacy in science

1. Students' posttest score of science process skills is statistically significantly higher than pretest score at .05 level.
2. Students' posttest score of science competencies is statistically significantly higher than pretest score at .05 level.
3. Students' posttest score of self-efficacy in science is statistically significantly higher than pretest score at .05 level.
4. Students' science process skills have correlation with science competencies.
5. Students' science competencies have correlation with self-efficacy in science.

CHAPTER 2
REVIEW OF THE LITERATURE

The purpose of this study is to enhance students' science process skills, students' science competencies, and students' self-efficacy in science by using the metacognitive strategy embedded in inquiry learning. This chapter is a review of literature which related;

1. Basic Education Curriculum B.E. 2551 in Thailand
2. Science process skills(SPS)
   - 2.1 The categories of science process skills
     - 2.1.1 Basic science process skills (BSPS)
     - 2.1.2 Integrated science process skills (ISPS)
   - 2.2 The importance of science process skills
   - 2.3 Development students' science process skills
   - 2.4 Assessment of science process skills
3. Inquiry-based learning
   - 3.1 Essential features of science classroom inquiry
   - 3.2 Implementing inquiry in science
4. The 5Es instructional learning model
   - 4.1 Phases of 5Es instructional learning model
5. Metacognition
   - 5.1 Inquiry learning influences metacognition and self-regulation in science education
   - 5.2 Metacognitive instruction
   - 5.3 Improving regulation of cognition
6. Self-efficacy and self-efficacy in science
   - 6.1 Self-efficacy
   - 6.2 Sources of self-efficacy
   - 6.3 Self-efficacy in science
   - 6.4 The importance of self-efficacy in science
   - 6.5 Assessment of self-efficacy in science

7. Science competencies

7.1 Assessment of science competence

1. Basic education curriculum B.E. 2551 in Thailand

The Basic Education Curriculum B.E. 2551 (A.D. 2008) stated that science is a subject that plays an important roles in the world community. It provides both scientific knowledge and enable learner to develop thinking skills, enable learner to acquire essential investigative skills for seeking knowledge, and including decision-making based on diverse data and evidence (Ministry of Education. 2008: 106; Sheeba. 2013: 109). The science curriculum standard indicates eight principle sub-strands for learners in basic education as follow;

Sub-strand 1: Living Things and Processes of Life

Sub-strand 2: Life and the Environment

Sub-strand 3: Substances and Properties of Substances

Sub-strand 4: Forces and Motion

Sub-strand 5: Energy

Sub-strand 6: Change Process of the Earth

Sub-strand 7: Astronomy and Space

Sub-strand 8: Nature of Science and Technology

This study will focus on sub-strand 6 and sub-strand 8 with expectation on learners in two standards as follow;

Standard Sc 6.1: Understanding of various processes on the Earth's surface and inside the Earth; relationship between various processes causing changes in climate; topography and form of the Earth; investigative process for seeking knowledge and scientific mind; and communication of acquired knowledge that could be applied for useful purposes.

Standard Sc 8.1: Application of scientific process and scientific mind in investigation for seeking knowledge and problem-solving; knowing that most natural

phenomena assume definite patterns that are explainable and verifiable within limitations of data and instructions of data and instruments available during particular periods of time; and understanding that science, technology, society and the environment are interrelated.

Summary:

The national science curriculum standards (the Basic Education Curriculum B.E. 2551) concluded that science education in Thailand focused on 3 major facets namely; scientific knowledge, scientific inquiry and scientific mind, and science communication. The curriculum demonstrated that process to acquire scientific knowledge is significant. Those process skills are added to Standard Sc 8.1 in each standard Sc of scientific knowledge. It emphasizes on process of acquired knowledge and solving problems, measurement, and investigation based on evidences. Therefore, students' science process skills are important including; Observing, Using space/time relationship, Classifying, Using number, Measuring, Communicating, Predicting, Inferring, Controlling variables, Interpreting data, Formulating hypotheses, Defining operationally, and Experimenting. These skills are as the tools to inquire and communicate in science.

This study emphasizes to develop students' science process skills (13 skills) which are the key for inquiry and solving problems include science communication for attaining the standard science of the national science curriculum standards (B.E. 2551).

2. Science process skills

As the statement of problems from teachers' opinion is students lacking of science process skills and less concern while learning. These problems are significant and need to be improved because it is the important process to acquire scientific knowledge. The PISA 2015 definition of scientific literacy framework is changing to more focus more on procedure by elaborating the concept of "knowledge about science" of PISA 2006 framework, split into two components—procedural knowledge and epistemic knowledge which related to knowledge of how ideas are produced and an understanding of the underlying rationale for these procedures and the justification for their use. The measurement of PISA 2015 is valuing scientific approaches to inquiry (OECD. 2013: 10-11).

According to PISA 2015 framework, procedural knowledge is the knowledge of the concepts and procedures that are essential for scientific inquiry which supports the collection, analysis and interpretation of scientific data. Moreover, one can define as knowledge of the standard procedures scientists use to obtain reliable and valid data. Definition of procedural knowledge by details is below (OECD. 2013: 19);

1) The concept of variables including dependent, independent and control variables

2) Concepts of measurement *e.g.*, quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables

3) Ways of assessing and minimizing uncertainty such as repeating and averaging measurements

4) Mechanisms to ensure the reliability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure)

5) Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use

6) The control of variables strategy and its role in experimental design or the use of randomized controlled trials to avoid confounded findings and identify possible causal mechanisms

7) The nature of an appropriate design for a given scientific question *e.g.*, experimental, field based or pattern seeking

Considering those procedural knowledge definition, it is similar as the set of science process skills (SPS) that consists of 1) Defining variables operationally, 2) Observing, 3) Classifying, 4) Measuring, 5) Inferring, 6) Communicating, 7) Interpreting data, 8) Identify and controlling variables, 9) Experimenting, 10) Predicting, 11)Formulating hypotheses, 12) Using number, and 13) Using space/time relationship. Table 1 showed how procedural knowledge of framework 2015 related to the set of science process skills;

TABLE 1 The consideration of procedural knowledge and science process skills

Details of Procedural Knowledge	Science Process Skills
The concept of variables including dependent, independent and control variables	Defining variables operationally
Concepts of measurement *e.g.*, quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables	Observing, Classifying
Ways of assessing and minimizing uncertainty such as repeating and averaging measurements	Measuring
Mechanisms to ensure the reliability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure)	Measuring
Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use	Communicating Interpreting data
The control of variables strategy and its role in experimental design or the use of randomized controlled trials to avoid confounded findings and identify possible causal mechanisms	Inferring Identify and controlling variables
The nature of an appropriate design for a given scientific question *e.g.*, experimental, field based or pattern seeking	Experimenting Predicting Formulating hypotheses

Moreover, some studied also refers procedural knowledge definition as basic scientific process skills (classifying and making observation) and integrated science process skills (drawing hypothesis, controlling the variables, planning an investigation, and collecting data (Surif; Ibrahim; & Mokhtar. 2012).

2.1 The categories of science process skills

The American Association for the Advancement of Science (AAAS) established a programme named Science—A Process Approach (SAPA) which emphasis to develop

students' competencies to apply a scientific mode of thought to problems and can be applied in other subject area as well. SAPA also attempts to develop in students' intellectual and investigative skills of the scientist; therefore it is focusing on scientific processes: observing, classifying, using numbers, measuring, space/time relationships, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables, and experimenting.

The SAPA has categorized process skills into eight basic and five integrated processes. The basic (simpler) science (BSPS) process skills provide a foundation for learning the integrated science process skills (ISPS) which is more complex (Sanderson& Kratochvil. 1971: 34; Padilla.1990). Basic science process skills is appropriate for learning concept formation at primary school and junior secondary school level while integrated science process skills is appropriate for students who learning science at secondary and tertiary school levels for formation of models, experimentation and differentiation (Gacheri; & Ndege. 2014: 102-131). Likewise, Burns; Okey; & Wise (1985) stated that integrated science process skills are vital aspect of meaningful laboratory activity at middle and secondary school.

2.1.1 Basic science process skills (BSPS)

By details of eight basic science process skills are summarized by Padilla (1990) and Sheeba (2013) as following:

1) ***Observing*** is using five senses (seeing, hearing, smelling, tasting and touching) to gather information about objects and events for getting their properties or changing. *Example*: describing a lemon as yellow. *Competency indicators*-- using one or more senses to collect the information about objects or events, Identify the properties of an object such as shape, color, taste, texture, Telling the similarities and differences between the objects, Match objects and given description;

2) ***Classifying*** is grouping objects or events into categories based on information collecting and according to objectives. Information can be classified at many types and levels; from very general to very specific. *Example*: placing all breads having certain color into one group. *Competency indicators*-- identify properties useful for

classifying objects, Group objects by their properties, similarities and difference, criteria, observation traits, Construct and use classification systems in tabular and other visual forms.

3) ***Measuring*** is making information from observation clearly by comparing some attribute of a system to a standard of reference. It also can be stated the process of making information observation into numerical term. All scientific measurement should be given in SI units. However, measuring use both standard and non-standard measures/ estimates to describe the dimensions of an object or event. *Example*: using the ruler to measure the length of notebook in centimeter. *Competency indicators* -- measure in given situation using appropriate units to suitable degree of accuracy, Use both standard and non-standard measures and estimates to describe the dimensions of an object, Use both standard and non-standard measures and estimates in making comparisons or taking readings.

4) ***Using space/time relationship*** is the process skills of relationships deals with the interaction of variables. Relationships can be multiple or single dimensions such as speed with distance and time representing is the example of two dimensions or the location in space is the example of single dimension. *Competency indicators*-- describe an object's position i.e. above, below, beside, etc., in relation to other objects, Describe the motion, direction, spatial arrangement, symmetry, and shape of an object compared to another object, Design patterns or interrelationship in a coherent manner and shape that promotes scientific appreciation and aesthetic sense.

5) ***Using number*** is represented observation information in terms of numbers. Identify quantitative relationship in nature. Using number can be reduced the verbal meaning and allowed to apply logic of mathematics to describe and understand nature. *Competency indicators*-- compute results from raw data, Apply numerical values in place of variables and vice-verse to generate meaning, Resolve theoretical dilemmas in an academic pursuit using mathematical figures of scientific significance.

6) ***Communicating*** is the process of presenting information of objects or events to people by taken in many forms: verbal, written, non-verbal, or symbolic. This process moreover refers to a group of skills which using to present in form of reporting data. It mostly has display in terms of tables, charts and graphs. *Competency indicators*--

translate information into other forms such as graphs, tables, and charts, Read information given in the form of graphs, tables, etc., decide the best way of presenting information of a certain kind.

7) ***Predicting*** is a process which forecasts future outcome based on information and evidence existed. Prediction must be testable. *Example*: Predicting the height of a plant in two weeks' time based on a graph of its growth during the previous four weeks. *Competency indicators*-- make use of evidence to formulate the sequence of a forthcoming process of action or outcome, Use patterns or relationships to extrapolate to case where no information has been gathered, Forecast events based on observations/ previous experiences/ certain patterns of reliable data.

8) ***Inferring*** is explanation or interpretation of an observation which be generated from "educated guess" about events or objects based on gathering data and information. Direct observation of events or objects is important because it enable people explain and interpret things. *Example*: Saying that the person used to walk long distances because his shoes were well worn. *Competency indicators*-- suggest explanations for events based on observations, Analyses the cause and effect of decision, Organize the observed data in a logical sequence leading to possible solutions.

However, Funk et al (1979) suggested that basic science process skill are interdependent, implying that students could use and apply more than one skill in any activity (Funk et al. 1979 cited in Sheeba. 2013).

2.1.2 Integrated science process skills (ISPS)

It is consisted of 5 process skills that summarized from Padilla (1990) and Sheeba (2013) as following;

1) Defining operationally is to define the attributes of variables to a concept by specific and be able to state method to measure those variables. *Example*: stating that bean growth will be defined as the amount of change in heights as measure from the top of soil to the tip of the longest stem in centimeters per week. *Competency indicators are*-- state how to measure a variable in an experiment, define the variable according to the actions or

operations to be performed on or with it, formulate a meaningful statement that generates a sense of understanding.

2) Formulating hypotheses is the expected outcome of an experiment. *Example*: the greater the amount of organic matter added to the soil, the greater the bean growth. *Competency indicators are*-- identify questions or statements which can and cannot be tested design statements, i.e., questions, inferences, predictions, which can be tested by an experiment, state the expected outcome of an experiment, develop testable explanation, explain a given observation in terms of conceptual relationships.

3) *Interpreting data* is organizing and analyzing data to draw conclusions from it. *Example*: recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables. *Competency indicators are*-- identify the relationship between the variables, from a given graph / table of data (relating to an investigation), draw conclusions from the data by determining apparent patterns or relationships in it, form a reasonable conclusion which relates trends in the data to variables.

4) *Identify and controlling variables* is to identify variables that can affect an experimental outcome keeping most constant while manipulating only the independent variable. *Example*: Realizing through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans. *Competency indicators are*-- identify the manipulated (independent) variable, responding (dependent) variable, and variables-held-constant in an experiment, identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable, identify the variables that may affect the dependent variable as stated in a problem, assign the limits of control of the selected variable in an investigation, propose degree of freedom of variables in an experiment to test hypothesis, control the variable in an investigation.

5) *Experimenting* is to be able to conduct an experiment, making appropriate questions stating a hypothesis, identify and controlling variables, operationally defining those variables designing a “fair” experiment, conducting the experiment, and interpreting the results of the experiment. *Example:* the entire process of conducting the experiment on

the affect of organic matter on the growth of bean plants. *Competency indicators are*-- identify what is to be measured or compared in a given investigation, select a suitable design for an investigation to test a hypothesis, recognize limitations of methods and tools used in experiments, i.e. experimental error, utilize safe procedures while conducting investigations, using appropriate apparatus.

Padilla suggested that learning needs more complex skills via experiment abilities that need to be practiced over a two weeks (Padilla. 1990). Moreover, the study of Junping (2011) suggested that teachers should measure students' basic science process skills to know the performance. If students were found weak in any skills, they needed to be improved their skills before giving students practice in integrated science process skills because some skills are required again in integrated science process skills such as observing and communication (Junping. 2011; Brotherton & Preece. 1995 cited in Sheeba. 2013).

2.2 The importance of science process skills

A science process skill is an important aim of science education for several reasons. As the science process skills is reflection of methods that scientists have used for generating information on science (Sheeba. 2013). It provides students to investigate the evidence to conclusion and emerging of scientific knowledge. The experiences from investigation of science such as designing experiments, gathering information from many resources by making predictions or to pose questions, collecting evidence to test the prediction or explore the answers and interpreting the results. These processes lead students given expansion their concepts (small idea) to explain the phenomena (big idea) reasonable (Harlen. 1999). Students are acquired more understanding in science like Keil, Haney, and Zoffel (2009) found that mastery of science process skills enables students to understand, at a much deeper level. Science process skills is crucial for development of understanding in science (Harlen. 1999) likewise Preece & Brotherton (1997) suggested that teaching science process skills in secondary school year have long-term effects on students' achievement. Moreover, one of vision of science literacy is to consider the products and process of science (Yager. 2002). According to science process skills include the

processes which can be applied the procedures in almost every stage of live of individual (Sheeba. 2013); provide individual to develop problem-solving skills, communicating skills, and critical thinking. Thus, science process skills is called as the core skills for learning (Sheeba. 2013; Harlen.1999) and the development of scientific process skills has to be a major goal of science education. At present, it is acknowledged in curriculum statements worldwide (Harlen. 1999).

2.3 Development students' science process skills

Many approaches are used to develop students' science process skills. The researcher has analyzed 15 studies related to science process skills development, conducted during year 2009 – 2015. The summary of previous studies in science process skills development is shown in Table 2. The study of Rauf et al (2013) stated that using various teaching approaches in a single lesson can create more opportunities for inculcation and acquisition of science process skills in the class. Especially, teacher should make proper planning and guidance when teach each skill. Skills with abstract should be developed through the teacher's facilitating ability while teaching including using any kind of approaches. Discussion approach seems suitable approach to inculcate the most science process skills. However, some skills; measurement and using of numbers and defining operationally need to be taught explicitly so, the discussion activities should be planned and given more clearly guidance. This studied also found that allowing students do the experiment by follow the procedure in lab sheet lead students do not aware which variables through forming hypothesis. Consequently, students were not aware of the importance of identifying the variables and its implementation when they make the conclusion to experiment. So, teacher should ask students to identify the variables involved before doing experiment and should given students exploration questioning (Rauf; et al,. 2013: 47 - 57).

Mollozzi and Heilbronner (2013) studied the using of an Interactive Student Notebook (ISN) Specific Written Feedback affects to seventh grade Students' science process skills. Three types of instruction were used in the studied; 1) a science instructional program using ISNs embedded with metacognitive strategies and specific written feedback (treatment), 2) instruction with using ISNs embedded with metacognitive strategies only

(comparison), and 3) a traditional science by using regular classroom instructional practices (control). Finding, there were no significant differences between the control group and treatment group or the comparison and treatment groups. Even a teacher participant stated the teacher's comments were read by students and they used it to improve science learning. However, two of three teacher participants feel stressed especially when teaching multiple lab classes they do not have time to provide the feedback to students, its process was time consuming. Moreover, the student survey is shown that 21.43% of responses indicated that specific written teacher feedback was not helpful as they usually received the feedback after the lab already completed; all directions already clear. The study demonstrated that using the ISNs with metacognitive strategies embedded (without feedback) lead to student participants get better understanding of concepts and impacted students' science process skills over traditional science instruction. The qualitative finding also indicated that both teachers and students liked using the ISNs for science labs and they did believe that ISNs was benefit for learning science process skills because of the application of metacognitive strategies (Mollozzi; & Heilbronner. 2013: 1 - 22).

Anagun (by abstract) studied the applying constructivist approach to develop students' science process skills. The qualitative results showed that constructivist approach could develop some sub-skills; observing, classifying, predicting, forecasting, collecting knowledge and data, and processing and forming model than inference and designing experiment sub-skills (Anagun. 2009: 843).

The approach relates to constructivist is also confirmed by the study of Vaithyanathan& Sivakumar (2013) expressed that science process skills can be acquired through cognitive constructivist approach (CCA) as this approach concentrates on how to think and how to understand things, it is active learning. Furthermore, constructivist classroom learns to question things which lead students to curious the world (Vaithyanathan; & Sivakumar. 2013).

The using of argumentation based concept cartoon activities influenced to integrated science process skills more than basic science process skills. In other words, it can be improved students' science process skills; experiment-devising and data-recording skills while only one sub-skills of basic science process skill to be improved; predicting skills.

As these results, may because of their reviewed literatures have found students' predicting skills was low level included the analyzing of science and technology course books in term of science process skills have found large numbers for observation and inference embedded in activities but mediocre level of data collecting and devising experiments. Consequently, their study intended for predicting. Moreover, they suggested that integrated science process skills needed to devise experiment. So, students needed to be treated by open-end inquiry or guided inquiry. The learning methods; argumentation-based learning, problem-based learning, and project-based learning method could support these skills. Especially, project-based learning method seems more effective on the skills like observation, devising experiment, and making inference (Turkoguz; & Cin. 2014: 146-151).

The using of self-regulated learning approach can improve pre-service science teachers' science process skills. By details, the experimental group was developed metacognition skills embedded within a motivating lab. Students were given to make pre- and post-discussions about the design of the experiments in order to create metacognitive awareness of the experimental design through scientific knowledge and science process skills in regards of each experiment. The students always provided positive feedback. If the report was not good sufficiently, the feedback would be the sentence with encouragement and focus on effort like "I believe that you can do much better if you try". The teaching method consisted of five phases: preparatory, awareness and planning, performing the experiment, self-control, and self-assessment and reflection. When the subscale of science process skills test (SPST) was analyzed, it could be seen that students in experimental group performed better than students in control group in terms of science process skills. In other words, developing students' metacognitive awareness within a motivating laboratory can improved science process skills namely identifying variables, operationally defining, and designing investigation. Moreover, the statistic showed that teaching method affected the students' motivational beliefs in terms of the scores of some subscales and students' self-efficacy beliefs of experimental group were significantly higher than students in control group. The students tended to believe their success or failure depends on their efforts for doing tasks (Saribas; & Bayram. 2009: 61 – 71).

Jeenthong and et al (2014) used the learning unit on aggressive behavior of Siamese fighting fish (*Betta splendens*) by three-phase learning cycle-based instructional including exploration phase, concept introduction phase, and concept application phase to enhance integrated science process skills and behavior animal concept. Even the posttest scores of experimental group are all significantly higher than pretest score and most students satisfied with the learning unit but they found some problems in designing and conducting the experiment during the exploration phase. They also suggested that students' prior knowledge, students' learning style, students' learning process, number of students in the class, and time limitation are the factors to concern for successful implementation.

Many studies have used 5E (Rompayom. 2010) and inquiry learning to improve students' science process skills in terms of basic or integrated science process skills (Şimşek; & KabapÕnar. 2010; Koksala; & Berberoglu. 2012; Lati.; Supasorn; Promarak. 2012; Yadav; & Mishra. 2013; Aydoğdua; Buldur; & Kartal. 2013; Ogan-Bekiroğlu; & Arslan. 2014; Chairam; Klahan; & Coll. 2015). Using of laboratory based on the 7E learning cycle model in General Physics Laboratory course at freshman university students improved four subscale of science process skills; observing, classifying, hypothesis, and inferring (Yadav; & Mishra. 2013). Some studies indicated that inquiry based learning lead impact to science process skills and students' attitudes towards science (Koksala; & Berberoglu. 2012) but some studies did not have impact on students' attitudes towards science (Rompayom. 2010; Şimşek; & KabapÕnar. 2010). Şimşek & KabapÕnar (2010) emphasized that timing for making attitude change would require more than 8 weeks of teaching. Guided inquiry learning seemed active to improve students' science process skills (observing, classifying, proposing hypotheses, controlling and manipulating variables, processing data, and formulating model) as it was used in the study of Koksala & Berberoglu (2012). They also stressed that guided inquiry was a transition approach between traditional teaching method (teacher-centered) and student-centered activities, function effectively for teacher who is not familiar with inquiry-based approaches. Moreover, Ogan-Bekiroğlu & Arslan(2014) used this approach in the control group to compare with model-based inquiry learning (experimental group), it indicated that guided inquiry could improve pre-service physics teachers' skills in

terms of identification of variables and stating hypothesis while using model-based inquiry learning enhanced two more dimensions; operationally defining, and data and graph interpretation. The insertion of a POE (predict-observe-evaluate) activity in the first inquiry feature was used to encourage students to find out the engaged question through inquiry process as the results of science process skills; identifying and controlling variables, defining operationally, formulating hypotheses, and experimenting were improved at the excellent and good level. However, interpreting data and drawing conclusion was fair and the authors stated that students may be weak in drawing conclusion during time limitation (Lati; Supasorn; Promarak. 2012). Likewise, the studies of Kruea-In & Thongperm (2014) suggested that many factors affect the promotion of science process skills namely students' ability, students' interesting, teachers' beliefs, attitudes, and teamwork. Time constraint was stated by secondary science teachers as the obstacle in that studied.

Moreover, Padilla (1990) suggested that integrated science process skills required inquiry. However, metacognition instruction is the second most popular used. Many studies indicated that significant differences were not observed but by details of approach it seems suitable to address the problem of this study.

TABLE 2 The used approaches for developing science process skills

Authors	Titles	Participants	Approaches
1 Rauf; et al.(2013)	Inculcation of Science Process Skills in a Science Classroom	Grade 8	Various approach in single lesson
2 Mallozzi; et al. (2013)	The Effect of using Interactive Student Notebooks (ISN) and Specific Written Feedback on Seventh Grade Students' Science Process Skills	Grade 7	Metacognitive instruction + Interactive notebook + feedback + science lab
3 Anagun. (2009)	Developing scientific process skills at Science and Technology course in fifth grade students	Grade 5	Application of constructivist approach

TABLE 2 (continued)

Authors	Titles	Participants	Approaches
4 Vaithyanathan; et al. (2013)	Effectiveness of Cognitive Constructivist Approach In The Acquisition of Science Process Skills	Grade 9	Cognitive Constructivist Approach (CCA)
5 Turkoguz; et al. (2014)	Effects of Argumentation Based Concept Cartoon Activities on Students' Scientific Process Skills	Grade 7	Argumentation Based Concept Cartoon Activities
6 Saribas; & Bayram. (2009)	Is it possible to improve science process skills and attitudes towards chemistry through the development of metacognitive skills embedded within a motivated chemistry lab? : A self-regulated learning approach.	pre-service science teachers	Development of metacognitive skills: self-regulated learning approach.
7 Yadav; & Mishra. (2013)	A study of the impact of laboratory approach on achievement and process skills in science among Is standard students	Freshman university students	laboratory based on the 7E learning cycle model
8 Şimşek; & KabapÕnar. (2010)	The effects of inquiry-based learning on elementary students' conceptual understanding of matter, scientific process skills and science attitudes	Grade 5	Inquiry-based Learning (IBL)

TABLE 2 (continued)

Authors	Titles	Participants	Approaches
9 Aydoğdua; Buldur; & Kartal. (2013)	The effect of open-ended science experiments based on scenarios on the science process skills of the pre-service teachers	pre-service teachers	Open-ended science experiments based on scenarios
10 Lati; Supasorn.; Promarak. (2012)	Enhancement of learning achievement and integrated science process skills using science inquiry learning activities of chemical reaction rates	Grade 11	12 hours of science inquiry activities
11 Jeenthong; et al. (2014)	Promoting integrated science process skills through betta-live science laboratory	Grade 11	Betta-live science laboratory by using three-phase learning cycle-based instructional: exploration phase, concept introduction phase, concept application phase.
12 Ogan-Bekiroğlu; & Arslan. (2014)	Examination of the effects of model-based inquiry on students' outcomes: scientific process skills and conceptual knowledge	Five-year pre-service teacher	Model-Based Inquiry: to emphasize that scientists: engage in inquiry other than controlled experiments, use existing models in their inquiries, use models to construct explanations, engage in argumentation

TABLE 2 (continued)

Authors	Titles	Participants	Approaches
13 Koksala; & Berberoglu. (2012)	The effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science	Grade 6	Guided-inquiry approach
14 Rompayom. (2010).	Development of "Chemical Bonding" learning units in incorporated with elicitation strategy for high school students	Grade 10	Learning units incorporated with elicitation strategy (5E + elicitation strategy)
15 Chairam; Klahan; & Coll. (2015).	Exploring Secondary Students' Understanding of Chemical Kinetics through Inquiry- Based Learning Activities	Grade 11	Inquiry-based Chemistry Laboratory

Summary:

Scientific literacy in PISA 2015 focuses more on scientific inquiry. It demonstrated that students should know the concept of procedures in order to investigate scientific knowledge through natural world. To acquire scientific knowledge, procedural knowledge or science process skills are required.

This study is aimed to develop students' process skills in experiments in science class including solving problems and making decision from information in their daily life. Therefore, this study has defined science process skills as students' abilities to use 13 process skills do the experiments including investigating natural world (knowledge) and thinking about problems for making decision.

The thirteen science process skills are categorized as the basic and integrated science process skills. Basic science process skills (BSPS) consists of 8 process skills namely; observing, classifying, measuring, using space/time relationship, using number, communicating, predicting, and inferring. Integrated science process skills (ISPS) consists of 5 skills namely; defining operationally, formulating hypotheses, interpreting data, identify and controlling variables, and experimenting. Each skill will be measured by competency indicators which will be constructed by researcher.

To develop science process skills based on the literature, inquiry based learning is an appropriate approach to promote science process skills. This study aims to use inquiry based learning (in terms of 5E Instructional Model) as a main model and will be inserted with metacognitive strategy approach (regulation of cognition) because by addressing problems like the lack science process skill and less concern while learning, not have working plan, doing wrong procedure, and cannot reflect purpose of experiment. These are demonstrating that students need more plans and the goals of the experiment or task including need to monitored during a process in the science classroom. The researcher realizes that problems need more planning and monitoring as a result the created learning model is infused between the 5E inquiry and regulation of cognition.

Moreover, this created learning model includes some techniques; POE, ISNs, and pre- & post- discussion about laboratory design in this study model.

2.4 Assessment of science process skills

Assessment of science process skills can be assessed as formative and summative. The paper–and-pencil test is popular used in terms of summative assessment in order to determine grades, write evaluations, and compare levels of achievement (Harlen. 1999; McColskey; & O' Sullivan. 2000; The Exploratorium and institute for inquiry. 2006).

Formative assessment provides information for measuring and adapting teaching method which help students get closer to the learning goals. Teacher gathers students' work and information to determine what students need to do next (Harlen. 1999: 133; The Exploratorium and institute for inquiry. 2006: 13). The information can be gathered by:

1. Observing pupils—this includes listening to how they describe their work and their reasoning. It can be in terms of informal or formal observation. Formal observation have a specified focus and sample behavior to be observed systematically while informal observation is observed with no predetermined focus. However, if teacher want to evaluate students' progress by seeing how students increase their ability to work independently with the material lab. Teacher may develop a structured observation form for the lab to record information (Harlen.1999; McColskey; & O' Sullivan. 2000).

2. Interviews —it may focus on a cognitive or even what students understand about a particular topic, how students feel. Even interviews with students are time-consuming, but some are worth for; students who seem to be having trouble with particular concept or skills as demonstrated on their test, students which are different abilities about prior knowledge, students who have difficulty with written to express what they understand in a context, and provide the teacher opportunity to probe and ask follow-up questions which challenge students to think beyond their current level of understanding which organize their knowledge in more systemic ways (McColskey; & O' Sullivan. 2000).

3. Self-Assessment Questionnaires — it makes teacher knows how students perceive their knowledge and skills, the quality of their work, the concern they have about their progress, their prior level of experience with a topic or skill. The teacher might give to students at the beginning of the year to better understanding their interest and their science background such as the laboratory instrument (McColskey; & O' Sullivan. 2000).

4. Questioning— using open questions, phrased to invite pupils to explore their ideas and reasoning; asking pupils to communicate their thinking through drawings, artefacts, actions, role play (Harlen. 1999: 133).

5. Open-Ended Questions— it is appropriate to assess student performance on more complex cognitive outcomes. The length of response can vary. It depends on the age of students, the question asked, and time provided to complete the question. The questions might relate to: formulate a hypothesis or conclusion, describe the limitations of the data, explain a method or procedure, and create or design something i.e., an experiment (McColskey; & O' Sullivan. 2000).

6. Performance Tests/ Tasks— setting tasks in a way which requires pupils to use certain skills. Students actually perform the tasks rather than take a paper-and-pencil test to assess students. It can be demonstrated their competencies. For example, students are expected to be competent at measurement using different instrument or at using lab equipment such as microscopes (Harlen. 1999; McColskey; & O' Sullivan. 2000).

7. Journal— it can reflect students on what they are learning, and foster students' active involvement in classroom activities. It also used to assess attitude towards science (McColskey; & O' Sullivan. 2000).

8. Interactive Student Notebook (ISNs)— ISNs are the spiral notebooks which consist of two parts; Input (right side) and output (left side). The right side consists of information received, note, information obtained from text, and lab guides. The left side consists of students' interpretation and their reflections see Figure 3. It was used in the study of Mallozzi (2013).

Moreover, using the formative assessment cycle can help teacher to improve student performance in science process skills (see Figure 2).

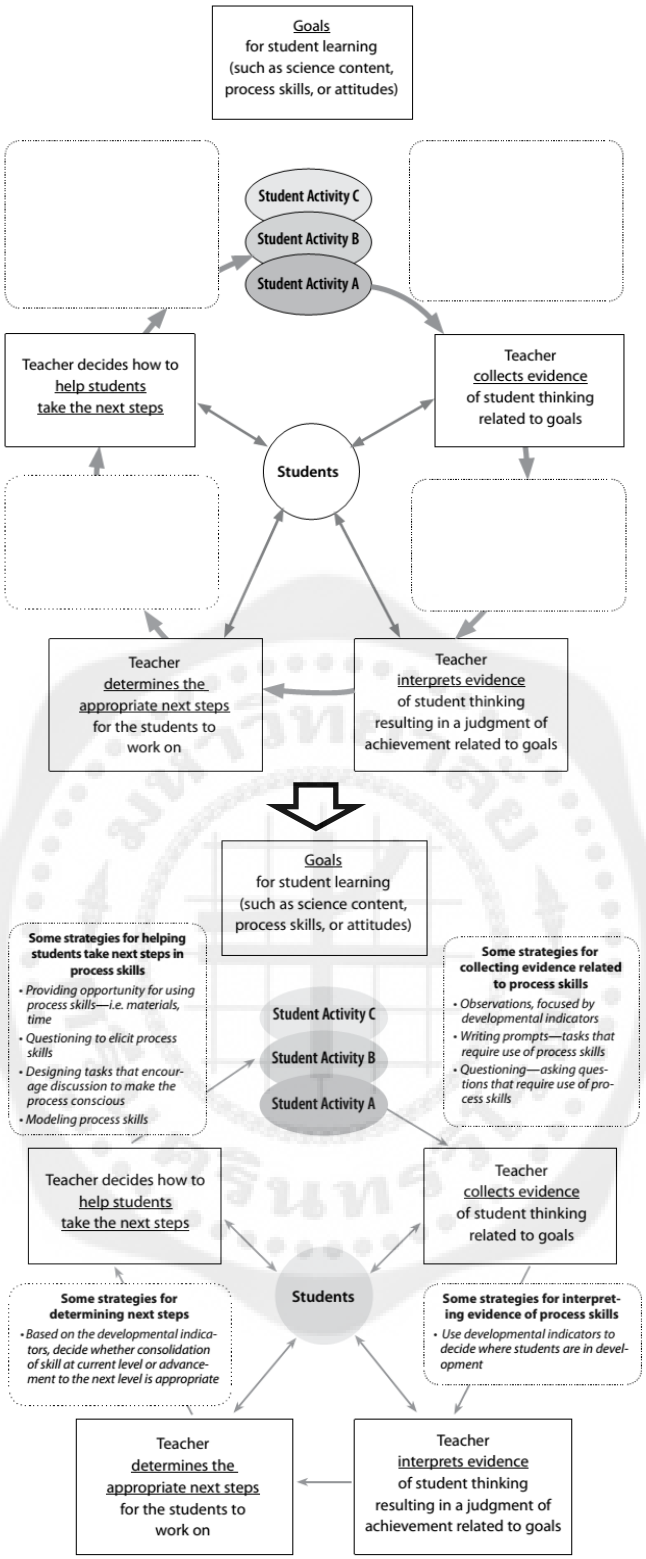

FIGURE 2 Formative assessment cycle

Source: adapted from The Exploratorium and institute for inquiry. (2006). Workshop II: Assessing process skills. A Professional Development Curriculum. p.53 & 73.

Left side of notebook:	Right side of notebook:
Interpretation: Conceptual Diagram Reflection: Connection: Extension: I noticed that… This made me wonder if…	Lab Title: _____ PRE LAB Safety rules addressed: _____ _____ Purpose/Problem (research question) _____ _____ Why is this important? (relevancy) _____ Prior knowledge and background information: _____ _____ State your hypothesis – (What are you claiming?) _____ _____ Independent Variable: _____ Dependent Variable: _____ Control: _____ LAB: List materials: Procedures: Define specific vocabulary or terms you will use… How will you measure? How many trials will you perform? Why? Record observations Data presentation: Choose how you will represent your data collection/evidence: data table, graph, etc. Results: Explain your findings (analysis) Conclusion: (evidence based on your data) What would you change if you did this lab over?

FIGURE 3 Example of an opened interactive student notebook (ISNs)

Source: Mallozzi, Floria. (2013). The Effects of Using Interactive Student Notebooks and Specific Written Feedback on Seventh Grade Students' Science Process Skills. Figure 2 p. 11.

Summary:

In this study, formative and summative assessment will be used to evaluate science process skills. In terms of formative assessment, data will be gathered by observing, questioning, the performance from given tasks, the experiment report (ISNs), and communicating. The science process skills test which is constructed by researcher will be used as the summative assessment.

3. Inquiry based learning

Inquiry has had a role in school science programs for less than a century (Bybee; & DeBoer. 1993; DeBoer. 1991 cited in NRC. 1996). Before 1990, most educators viewed science as a body of knowledge and science was taught by direct instruction. Until in 1909, John Dewey stated that science is both a body of knowledge and process or method to learn (National Research Council. 2000). Dewey encouraged K-12 teachers of science to use inquiry as teaching strategy with rigid scientific method which consisted of six steps: sensing perplexing situations, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, revising with rigorous tests, and acting on the solution. In Dewey's model, the student was active, and a teacher role is act as facilitator. Students must address problems that they want to know and then observe that phenomena (Barrow. 2006).

By the 1950s and 1960s, inquiry was becoming increasingly popular approach to teach science and the educator, Joseph Schwab was an influential voice to establishing view of how to learn through active engagement in process of inquiry in science education. He stated that science should be viewed as conceptual structures that were revised as the result of new evidence. The evidence should be built to explain and the refinement of explanations (National Research Council. 2000).

Inquiry is an active learning process which engages students learning with meaningful (NSES cited in Anderson. 2002; Barrow. 2006: 266). It was used in various fields of education especially, science. The National Science Education Standards (NESE) stated that "scientific inquiry is at the heart of science and science learning" (National Research Council. 1996: 15). The National Science Education Standards (NESE) has given that scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (National Research Council. 1996: 23). It plays as student-center and characterize of inquiry process is multifaceted activities namely observation, posing questions, examining sources of information, checking what already known and planning investigation, using tools to gather, analyze, explanation, interpret data and prediction, and communicating results. Moreover, it

requires identification of assumptions, use of critical thinking, and consideration of alternative explanations (National Research Council. 1996).

Consequently, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories (National Research Council. 2000). In other hand, it would say inquiry learning is related investigating, questioning, evidence, and explanations within a learning context.

3.1 Essential features of science classroom inquiry

Inquiry teaching and learning have five essential features that apply across all grade levels which National Science Education Standards (NSES) identified are;

1. The learner engages in scientifically oriented questions
2. The learner gives priority to evidence in responding to questions
3. The learner formulates explanations from evidence
4. The learner connects explanations to scientific knowledge
5. The learner communicates and justifies explanations

However, these five features can be varied. It might include the amount of structure a teacher build into activity or the extent which student design an investigation by them. Table 4 below shows the details for each feature. Inquiry based teaching and learning occurs when students' experiences are described by the right-hand column. The degree to which teachers structure what student do is sometimes referred to as "guided" and students do by himself/herself referred to "open" inquiry (National Research Council. 2000). The more “open” the inquiry (that is, the closer to the right column in Table 4), the more responsibility the teacher takes. The more guided the inquiry (that is, the closer to the left column on Table 3), the more responsibility the students take. The more opened the inquiry.

Variations of Table 3

Less ---------- Amount of Learner Self-Direction ---------- More

More ---------- Amount of Direction from Teacher or Material ---------- Less

TABLE 3 Essential features of classroom inquiry and their variations

Essential Feature	Variations			
1.Learner engage in scientifically oriented questions	Learner engages in question provided by teacher, materials, or other source	Learner sharpens or clarifies question provided by teacher, materials or other source	Learner selects among questions, pose new questions	Learner pose a question
2.Learner gives priority to evidence in responding to questions	Learner given data and told how to analyze	Learner given data and asked to analyze	Learner directed to collect certain data	Learner determines what constitute evidence and collects it
3.Learner formulates explanations from evidence	Learner provided with evidence and how to use evidence to formulate explanation	Learner given possible ways to use evidence to formulate explanation	Learner guided in process of formulating explanations from evidence	Learner formulates explanation after summarizing evidence
4.Learner connects explanations to scientific knowledge		Learner given possible connections	Learner directed toward areas and sources of scientific knowledge	Learner independently examines other resources and form the links to explanations
5.Learner communicates and justifies explanations	Learner given steps and procedures for communication	Learner provided with broad guidelines to use to sharpen communication	Learner coached in development of communication	Learner forms reasonable and logical argument to communicate explanations

Source: adapted from National Research Council. (2000). Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Table 2-6. p. 29

However, more specific on the content standard for science as inquiry: fundamental abilities necessary to do scientific inquiry for grade 5 – 8 by NRC (2000) are followed;

1. Identify questions that can be answered through scientific investigations.
2. Design and conduct a scientific investigation.
3. Use appropriate tools and techniques to gather, analyze, and interpret data.
4. Develop descriptions, explanations, predictions, and models using evidence.
5. Think critically and logically to make the relationships between evidence and explanations.
6. Recognize and analyze alternative explanations and predictions.
7. Communicate scientific procedures and explanations.
8. Use mathematics in all aspects of scientific inquiry.

3.2 Implementing inquiry in science

To implement inquiry in a science class, a teacher needs to understand and practice it. Basically, it should remembered that not all science concepts can or should be taught using inquiry. All of essential features probably cannot contain in the learning activity, but many features are present. It depends on students learning experience. The NSES suggested that students should have opportunities to participate in all types of inquiries in the course of their science learning, they also recommended that guided inquiry can best focus learning on the development of particular science concepts while more open inquiry will be best opportunities for cognitive development and scientific reasoning.

According to five essential features of classroom inquiry, it has emphasized on abilities of inquiry, questioning, evidence, and explanation within a learning context. The NRC (2000) points out that teacher should concern with;

1) *Scientifically oriented question*: every inquiry must engage students in a scientifically oriented question. These questions must be interested in by students, or iin other words, they will not establish ownership but it must be able to be answered by students' observations and scientific knowledge they obtain from reliable sources. The questions center on objects, organism, and events in the natural world that connect to

science concepts described in the content standards. “Why” questions cannot be addressed by science, instead of “How” questions will be narrowed and sharpened the inquiry and can make more empirical investigation, lead to gathering and using data to develop explanations for scientific phenomena. Therefore, the teacher plays a significant role in guiding the identification of questions.

2) *Giving priority to evidence*: the evidence is subject to questioning and further investigating, and empirical evidence is a basis for explanations. Consequently, the evidence gathered should be accurate which can be verified by checking measurements, repeating the observations, or gathering different kinds of data related to the same phenomenon.

3) *Formulating explanations from evidence to address scientifically oriented questions*: the scientific explanation is based on reason. They provide causes and effects and establish relationships based on evidence and logical argument. Moreover, even similar to previous feature, inquiry aspect focuses on the path from evidence to explanation rather than the criteria for and characteristics of the evidence.

4) *Evaluating explanations in light of alternative explanations, particularly those reflecting scientific understanding:* it may be revised by engaging in dialogues, comparing results, or checking their results with the proposal of a teacher, which leads students eliminate or revise explanations. This point can ensure that students make the connection between their results and knowledge appropriate to their level of development. Ultimately, students explanations should be consisted of currently accepted science knowledge.

5) *Communicating and justifying proposed explanation:* it provides others the opportunities to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations. These become clear articulation of the question, procedures, evidence, proposed explanation, review of alternative explanations including existing scientific knowledge. As a result, students can resolve contradictions and solidify an empirically based argument.

Anderson (2002) also recommended that science teachers' beliefs and values are related to students, teaching and purposes of education influenced to adoption and implementation of inquiry in science.

4. The 5Es instructional model

The 5Es model was developed from learning cycle which proposed by J. Myron Atkin and Robert Karplus in the early 1960s and used in the Science Curriculum Improvement Study (SCIS). Originally, Karplus began to design the instructional materials and science teaching based on the theory of Jean Piaget. The SCIS learning cycle consisted of three phases; exploration, invention, and discovery. Then this learning cycle was modified to exploration, term introduction, and concept application. After that the Biological Science Curriculum Study (BSCS) added initial phase designed to engage the learner's prior knowledge and a final phase to evaluate the students' understanding. It was named as "5E instructional model" which consist of five phases; engagement, exploration, explanation, elaboration, and evaluation (see Table 4). Since the 1980s, BSCS has used the 5E model as a central innovation in elementary, middle, and high school biology and integrated science programs (Bybee; et al. 2006).

TABLE 4 Comparisons of SCIS and BSCS instructional models

SCIS Model	BSCS 5E Instructional Models
	Engagement (new phase)
Exploration	Exploration (modified from SCIS)
Invention (Term Introduction)	Explanation (modified from SCIS)
Discovery (Concept Application)	Elaboration (modified from SCIS)
	Evaluation (new phase)

Source: Bybee, Rodger W; et al. (2006). The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications Executive Summary. Table 2. p. 2.

4.1 Phases of 5Es instructional model

The 5Es Instructional Model is developed by Science Curriculum Study (BSCS) consists of five phases; engagement, exploration, explanation, elaboration, and evaluation. By details are summarized as following (Bybee; et al. 2006):

(1) *Engagement* — The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.

(2) *Exploration* — Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation

(3) *Explanation* — The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.

(4) *Elaboration* — Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.

(5) *Evaluation* — The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

TABLE 5 The BSCS 5E instructional model: what the student and teacher do

Stage of the Instructional Model	The BSCS 5E Instructional Model: What they do	
	Student	Teacher
Engagement	Asks questions such as, “Why did this happen?” “What do I already know about this?” “What can I find out about this?” Shows interest in the topic	Creates interest Generates curiosity Raises questions Elicits responses that uncover what the students know or think about the concept or topic
Exploration	Thinks freely, within the limits of the activity Tests predictions and hypotheses Forms new predictions and hypotheses Tries alternatives and discusses them with others Records observations and ideas Asks related questions Suspends judgment	Encourages the students to work together without direct instruction from the teacher Observes and listens to the students as they interact Asks probing questions to redirect the students’ investigations when necessary Provides time for the students to puzzle through problems Acts as a consultant for students Creates a “need to know” setting
Explanation	Explains possible solutions or answers to others Listens critically to others’ explanations Questions others’ explanations Listens to and tries to comprehend explanations that the teacher offers	Encourages the students to explain concepts and definitions in their own words Asks for justification (evidence) and clarification from students Formally clarifies definitions, explanations,

TABLE 5 (continued)

Stage of the Instructional Model	The BSCS 5E Instructional Model: What they do	
	Student	Teacher
Explanation	Refers to previous activities Uses recorded observations in explanations Assesses own understanding	and new labels when needed Uses students' previous experiences as the basis for explaining concepts Assesses students' growing understanding
Elaboration	Applies new labels, definitions, explanations, and skills in new but similar situations Uses previous information to ask questions, propose solutions, make decisions, and design experiments Draws reasonable conclusions from evidence Records observations and explanations Checks for understanding among peers	Expects the students to use formal labels, definitions, and explanations provided previously Encourages the students to apply or extend the concepts and skills in new situations Reminds the students of alternate explanations Refers the students to existing data and evidence and asks, "What do you already know?" "Why do you think …?" (Strategies from exploration also apply here.)

TABLE 5 (continued)

Stage of the Instructional Model	The BSCS 5E Instructional Model: What they do	
	Student	Teacher
Evaluation	Answers open-ended questions by using observations, evidence, and previously accepted explanations Demonstrates an understanding or knowledge of the concept or skill Evaluates his or her own progress and knowledge Asks related questions that would encourage future investigations	Observes the students as they apply new concepts and skills Assesses students' knowledge and skills Looks for evidence that the students have changed their thinking or behaviors Allows students to assess their own learning and group-process skills Asks open-ended questions such as, "Why do you think …?" "What evidence do you have?" "What do you know about *x*?" "How would you explain *x*?"

Source: adapted from Bybee, Rodger W; et al. (2006). The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications Executive Summary. Table 13-14. p. 33-34.

Summary:

According to the BSCS 5E Instructional Model (integrated to 5E inquiry), in engagement phase, students need to consider their prior knowledge to response the scientifically oriented question for making connections. To evaluate process is found only the last phase of 5E model but do not evaluate in previous phases. During designing the investigation in the exploration phase, planning is existed by implicit. Even explanation and elaboration phases, students monitor and plan implicitly their new conceptual

understanding and skills through new experience to apply in challenge tasks. However, refer to address the problem of this study which has found problems in laboratory namely;

1) No working plan

2) Do not know how to propose the way to explore

3) Doing wrong procedure

4) Improper use of tools or equipment as required

5) Cannot reflect purpose of experiment

6) Drawing wrong conclusion

7) Cannot discuss about experiment

8) Cannot apply knowledge to daily life

9) Lack tools of science

10) Lack science process skills

For making concrete pursuits, students need to require more plans, monitor, and frequently reflect their processes in experiment explicitly. Consequently, researcher considers to use metacognition; in terms of regulation of cognition (consisted of plan, monitor, and evaluate) to insert into four phases of 5E inquiry. The framework of this study is based on concept of inquiry and metacognition as shown in Figure 4.

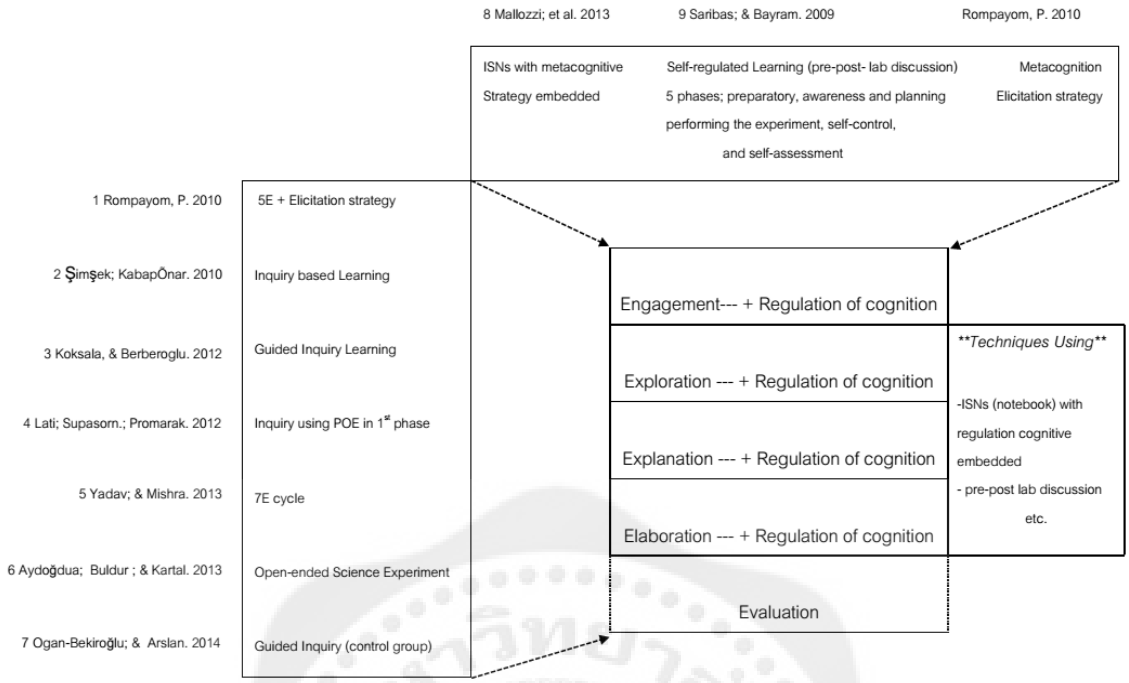

FIGURE 4 The selections of approaches and techniques used to develop science process skills in previous research

5. Metacognition

The definitions of metacognition are proposed by many researchers based on their frames. Those frameworks have mentioned about metacognition as two main constituent parts: metacognitive knowledge and cognitive regulation (Flavell. 1979; Cross; & Paris. 1988; Paris; & Winorad. 1990; Schraw; & Moshman. 1995). Metacognitive knowledge refers to knowledge about oneself and reflection about the state of ability (Flavell. 1979; Paris; & Winorad. 1990), understanding factors affecting cognitive and performance (Cross; & Paris. 1988; Schraw; & Moshman. 1995; Schraw; et al. 2006) including knowledge about strategy (Flavell. 1979) and know how to use and know when or why to use that given strategy (Schraw; & Moshman, 1995; Schraw; et al. 2006). While cognitive regulation has related to planning, monitoring or regulating, and evaluating (Paris; & Winorad. 1990; Cross; & Paris. 1988; Schraw; & Moshman. 1995; Schraw; et al. 2006) including metacognitive experience of Flavell (1979) which refers to the situations stimulate one to think and feel or judgment about own thinking to require planning or quality control for actions. For instance, you sense

(metacognitive experience) that you do not yet know a certain chapter in your text well enough to pass tomorrow's exam, so you read it through once more (cognitive strategy).

Metacognition plays a significant role in various aspects; in oral communication of information, oral persuasion, oral and reading comprehension, writing, language acquisition, attention, memory, problem solving, social cognition, and various types of self-control and self-instruction (Flavell. 1979: 906).

Therefore, Metacognitive instruction is applied for improving students' metacognitive thinking or "thinking about thinking" which lead to improve students' skills; reading skills, problem solving skills, higher-order thinking skills or students' knowledge and conceptual understanding. For science education, metacognition have used for study on both terms of independent and dependent variables. Such as to focus on methods for fostering learners' metacognition; to investigate the nature of students' or teachers' metacognition; to study the contribution of metacognitive instruction to the development of learners' scientific understanding, thinking or skills (Zohar; & Barzilai. 2013).

Schraw and et al (1995; 2006) was the researchers who have been studying on promoting metacognition in science education. They defined the metacognition as the ability to reflect upon, understand, and control's one learning (Schraw; & Dennison. 1994: 460).

According to Schraw (1998) and Schraw and et al., (1995; 2006) defined metacognition into two main subcomponents:

1. *Knowledge of cognition* refers to what individuals know about their cognition and include three subcomponents: declarative, procedural, and conditional knowledge.

1.1) *Declarative knowledge*— refers to knowledge about oneself as a learner and about factors influence to learner's performance;

1.2) *Procedural knowledge*— refers to knowledge about the execution of procedural skills, strategies. On other hands, it is known how to do things;

1.3) *Conditional knowledge*— refers to knowledge of why and when to use declarative and procedural knowledge.

2. *Regulation of cognition* refers to a set of activities that help students to control their learning. It consists of three components; planning, monitoring, and evaluating.

2.1) Planning— relates to the selection of appropriate strategies and allocation of resources. In other hands, all plans to be successful in tasks e.g., setting goal, manage time, prior knowledge.

2.2) Monitoring— refers to one's on-line awareness of comprehension and task performance including engage self-testing while learning.

2.3) Evaluation— refers to appraising the products and a regulatory process of one's learning.

They indicated that while knowledge of cognition and regulation of cognition are intercorrelated, it may work together to help students' self-regulate (Schraw; & Dennison. 1994:466) Additionally, Schraw and his colleagues (2006) stated that metacognition is related to self-regulated learning which refers to learners' abilities to understand and control their learning environment. Self-regulated learning involves three constituent parts; (1) cognitive which refer to skills necessary to encode, memories, and recall information which are formed of simple, problem solving and critical thinking strategy; (2) metacognition refers to skills that enable learner to understand and monitor their cognitive process in forms of knowledge cognitive and control of cognitive skills which involves planning, monitoring, and evaluating of learning; and (3) motivational refers to students' beliefs in their capacity which is formed of self-efficacy and personal epistemology beliefs that affect the use and development of cognitive and metacognitive skills. They also pointed out that to achieve a high level of self-regulation; each component must have a positive correlation. For example, those who are motivated but do not possess the necessary cognitive and metacognitive skills often fail to achieve on self-regulation while individual who possess and are motivated will be achieving see Figure 5.

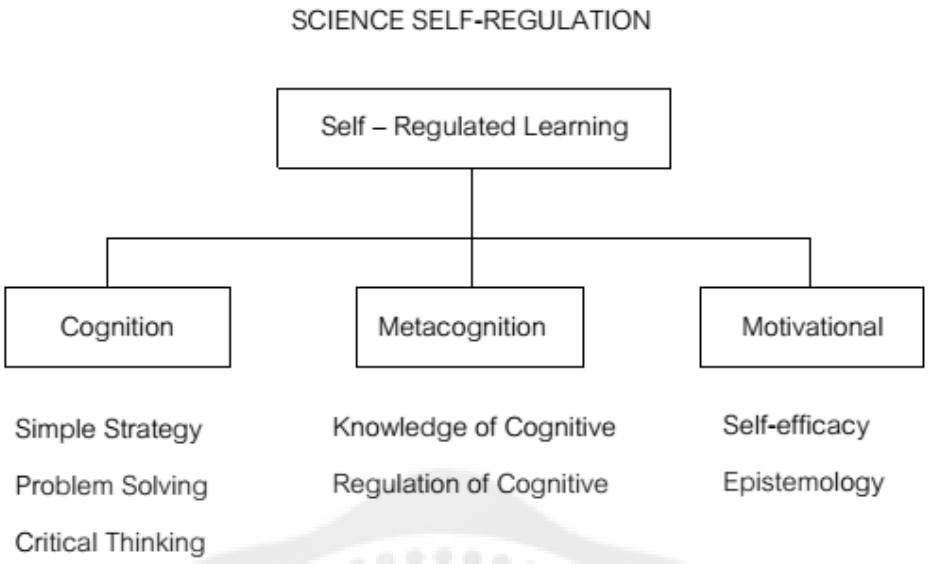

FIGURE 5 Components of self-regulation learning

Source: Schraw, Gregory; Crippen, Kent J; & Hartley. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Figure 1. p. 113.

By those constituents on Figure 6, Schraw and et al., (2006) believed that metacognition was an important role in science learning because metacognition enables individuals to monitor their current knowledge and skills levels, plan and allocate limited learning resources by efficiency, and evaluate their current learning state. As the results, they have found out the teaching which promotes metacognition in science.

5.1 Inquiry Learning Influences Metacognition and Self-regulation in Science Education

To promote metacognition in science, Schraw and et al (2006) proposed six general instructional strategies for improving self-regulation and learning. Those are inquiry, collaboration, strategies, mental models, technology, and personal beliefs. Those instructional strategies expressed that inquiry influenced to metacognitive processes especially in terms of improving explicit planning, monitoring, and evaluating see Table 6. Schraw and et al., (2006) have emphasized that authentic inquiry can be promoted self-

regulation in two ways. Firstly, it stimulates students' active engagement in the learning process by using cognitive learning strategies and metacognitive strategies to monitor their understanding. Secondly, it helps to increase motivation to succeed in science by using modeling, especially predict-observe-explain (POE) (Windschitl. 2002) or question-asking (Chin; & Brown. 2002: 522) is good modeling for active investigation strategies. In addition, Davis (2003) and Baird & White (1996 cited in Schraw. 2006) suggested that while students explore, students should be expected to explain verbally or writing the problem solving strategies used to solve problems. These can promote self-reflection which is an essential component of metacognitive understanding and self-regulation.

TABLE 6 The six instructional strategies increase cognitive, metacognitive, and motivational processes

	Cognitive process	Metacognitive process	Motivational process
Inquiry	Promote critical thinking through experimentation and reflection	Improve explicit planning, monitoring, and evaluation	Provides expert modeling
Collabo-ration	Model strategies for novices	Model self-reflection	Provide social support from peers
Strate-gies	Provide variety of strategies	Helps students develop conditional knowledge	Increase self-efficacy to learn
Mental Models	Provide explicit model to analyze	Promote explicit reflection and evaluation of the proposed model	Promote radical restructuring and conceptual change
Techno-logy	Illustrates skills with feedback. Provides models and simulates data	Helps students test, evaluate, and revise models	Provides informational resources and collaborative support
Persona l Beliefs	Increase engagement and persistence among students	Promote conceptual change and reflection	Promotes modeling epistemology characteristic of expert scientists

Source: Schraw, Gregory; Crippen, Kent J; & Hartley. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Table 1. p. 131.

5.2 Metacognitive instruction

Zohar & Barzilai (2013) analyzed and identified approaches for infusing metacognition in instructional practices. Finally, the explicit metacognitive activities which are designed to raise metacognition are following;

1) Explicit instruction—pedagogical practice which is taken from form of constructivist practices.

2) Practice and training —refers to repeated training and practice which provide opportunities to activating and apply knowledge of metacognition and regular of cognition in multiple tasks, problems, and contexts.

3) Metacognitive prompt— refers to questions, cues, or probes that are introduced in writing, by the teacher, by student peers, or in a computerized environment, with the aim of fostering metacognitive thinking.

4) Teacher-led metacognitive discussions—refers to students talk with teacher about their thinking and learning in order to encourage and develop metacognitive thinking.

5) Student-led metacognitive discussions—refers to metacognitive discussion were lead and managed by students such as done in planed structured or semi-structured ways.

6) Metacognition writing—refers to writing of journals, reports or short reflections. These make students have opportunities to reflect on, describe and analyze their thinking and learning.

7) Metacognition modeling—refers to activities which teacher demonstrates how he/she activates and applies knowledge of cognition and regulation of cognition in course of learning, these practices will be the model for students.

8) Concept mapping and other visual representations—refers to using the concept maps, graphic organisers, flowcharts, and visual representation in order to help students represent and share their thinking and learning.

9) ICT for metacognitive instruction—refers to digital information and communication technologies (ICT) were used for teaching and facilitating metacognition.

Schraw recommended that providing explicit prompts helps student improves their regulation abilities and students probably use a checklist with entries for planning,

monitoring, and evaluating which also help students get more systemic and strategic during problem solving (Schraw. 1998). Similarity, providing students with metacognitive questions: comprehension question, strategy question, and connection questions for completing task. Comprehension question can encourage students to reflect on a problem before solving it. Strategy questions can encourage students to think about what strategy might be appropriate for given task and provide a reason or rationale for that strategy choice. Connection questions can help students to identify and recognize deep-structure task attributes (Kramarski; & Mevarech. 2003: 286 -287).

5.3 Improving regulation of cognition

As the studies have reported when student have regulatory skills and understand how to use those skills in classroom instruction, their learning is improved (Cross & Paris. 1988; King. 1991 cited in Schraw. 1998; Schraw; & Dennison. 1994: 466). To improve regulation of cognition can be used these ways as follow;

1) Regulatory Checklist (RC)—is a model which was used by King (1991 cited in Schraw. 1998). It provides an overarching heuristic that facilitates the regulation of cognition (see an example of RC on Figure 6). He finally concluded that explicit prompt in the form of checklist can help students to be more strategic and systematic when solving problems especially enable the novice learners to train a systematic regulatory sequence and help them to control their performance.

Planning

1. What is the nature of the task?
2. What is my goal?
3. What kind of information and strategies do need?
4. How much time and resources will I need?

Monitoring

1. Do I have clear understanding of what I am doing?
2. Does the task make sense?
3. Am I reaching my goals?
4. Do I need to make change?

Evaluating

1. Have I reached my goals?
2. What worked?
3. What didn't work?
4. Would I do things differently next time?

FIGURE 6 A Regulatory checklist

Source: Schraw, Gregory.(1998). Promoting General Metacognitive Awareness. Figure 2. p. 121.

2) Self-monitoring—is used in the study of Delclos and Harrington (1991). The steps in self-monitoring process were quite similar to use RC of King (1991 cited in Schraw. 1998). The participants were given a booklet of questions to be used as monitoring their works on each practice problem see Figure 8. The questions were divided in three sections; before, during, and after students started to build the machine. If any machine did not solve the given problem when it was tested, the students needed to begin again, repeating those cycles as the same in another booklet. That study has shown that training with monitor students' solution process leads students were getting more effective for solving more complex problems and less spending time than training without monitoring. An example of self-monitoring is shown as following;

Before starting each game:

1. What is the title of the game you are about to play?
2. Are you determinate that you can win this game?
3. Have you looked at the problem carefully and thought about how to solve it?
4. Do you have an adequate background to build this machine? If not, where can you obtain it?

During running (after building the machine and before running):

1. Did you look for clues that would help you solve this problem? If so, check those used: (a) title of the game, (b) point values of the targets, (c) other (specify).
2. Did you redefine or clarity the problem? If so, How?
3. Did you break the problem into smaller parts? If so, what did you do?

After running the machine:

1. How many points did your machine score?
   If your machine scored less than 24 points, answer the following:
2. Have you looked for causes of bugs in your machine? (Please do so now.) What caused the bug(s)? (a) use of the wrong gate(s), (b) a glitch, (c) other.
3. Did you use available debugging tools to find the sources of bugs? If so, which ones did you use? (a) title of the game, (b) point values of the targets, (c) other.

FIGURE 7 Contents of monitored problem-solving booklets

Source: Adapted by researcher from Delclos, V.R; & Harrington, C. (1991). Effect of strategy monitoring and proactive instruction on children's problem-solving performance.

Summary:

Metacognition is defined by many researchers. The present study is designed to use metacognition definition based on Schraw et al., (2006) which consists of two components; knowledge of cognition (declarative knowledge, procedural knowledge, and conditional knowledge) and regulation cognition (planning, monitoring, and evaluating). The regulation cognition will be used to infuse with 5E model as input of this study. Because of the 5E model is familiar by Thai's classroom (Science Institute. 2013 cited in Chamrat. 2013: 8) and provides both exploration to learn and also given an opportunity to challenge students' understanding in scientific knowledge in elaboration phase.

However, authentic inquiry learning is strongly influential to metacognition especially in terms of the regulation of cognition (planning, monitoring, and evaluating). As during process of inquiry, it needs to monitor and plan or reflect the procedure from the beginning until last investigation for ensuring the acquired knowledge. In other hand, the metacognition is allusive in an inquiry processes. However, in the real science classes in Thailand, it cannot be authentic inquiry or even based on inquiry learning. Most of them probably can be guided inquiry and less conduct in the elaboration and evaluation phases (IPST (Biology). 2006). It seems less reflection or monitoring explicitly. As a result, students do not know what are they doing or cannot draw the conclusions etc. as the addresses of survey. The students should be given more plans, recheck, and evaluating the processes by training.

Consequently, this researcher would like to propose the metacognition strategy embedded in learning inquiry model to improve those problems. The learning model is designed by infusing regulation of cognition, 5E model, and inquiry learning that show on Figure 8. Some metacognitive instructions such as metacognitive prompt (regulation checklist), POE, student-led metacognitive discussions, and so on will be the strategic to role play on regulation (planning, monitoring, and evaluating). That regulation of cognition namely planning, monitoring, and evaluating were embedded in four phases of 5E: engagement, exploration, explanation, and elaboration. That regulation cycle was driven step by step; planning – monitoring – evaluating.

6. Self-efficacy and self-efficacy in science

6.1 Self-efficacy

Self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance (Bandura. 1994: 2; 2006: 309) and achieve specific results (Pajares. 1996: 546). Self-efficacy influences to outcomes of motivation (Bandura. 1994: 4; Zimmerman. 2000: 82; Bong; & Skaalvik. 2003: 10), self-regulatory processes (Bandura. 1994: 4; Zimmerman. 2000: 87), emotion (Bandura, A. 1994: 2; Bong , M; & Skaalvik. 2003: 10), cognitive, and performance: it is also a predictor of academic

achievement (Bong; & Skaalvik. 2003: 10;) such as science achievement and performance (Britner; & Pajares. 2006; OECD. 2007: 136).

Bandura stated a strong sense of efficacy enhances human accomplishment and personal well-being in many ways as it influences many aspects of human agency namely: choice behavior, effort expenditure and persistence, thought patterns and emotional reactions, and humans as producers for future (Bandura. 1986 cited in Bandura. 1994: 2).

Bandura stated that a strong sense of efficacy enhances human accomplishment and personal well-being in many ways as it influences many aspects of human agency namely: choice behavior, effort and persistence, including patterns and emotional reactions. When high self-efficacy people failed on something they would think about because of insufficient effort rather than deficient ability and can be quickly recover their sense of efficacy after failure or setbacks. They can exercise control over them and produce their own future rather than foretell it. By these attributes produces people who strong perceived self-efficacy to be an accomplishment, reduces stress, and lower vulnerability to depression. In contrast, people who doubt their capabilities tend to avoid difficult tasks, tend to believe that things are tougher than they really are which affect to be a narrow vision to find the ways to solve problems, feel deficient ability when faced difficult tasks, having low aspiration, and give up easily. Thus, they tend to fall easy victim to stress and depression (Bandura.1994: 2).

6.2 Sources of self-efficacy

There are four main sources related to develop level of self-efficacy (Bandura. 1994) and others are given recommends.

1. *Mastery experience:* it is the most influential to form perceived efficacy (Bandura. 1994; Pajares. 2005: 296; Britner; & Pajares. 2006: 486). It has been shown that girls have stronger science self-efficacy than that of boys in middle school (Britner; & Pajares. 2006: 486). Bandura stated that students perceived their capabilities through their previous outcomes of experience. Experience success raises confidence while experience failure raises low confidence. Therefore, strong sense of capabilities required repeat of success and also be promoted through the overcoming obstacles by much perseverance

(Bandura. 1994). Consequently, the tasks that teachers have given to students should not be too easy because if students experience with the only easy success they would expect quickly and would be easily discouraged by failure (Bandura. 1995: 3).

2. *Vicarious experience*: the way of creating and strengthening self-efficacy is through observing others perform tasks. If the similarity between role model and observer is much, their perceived self-efficacy is strongly influenced. Such as people similarly can be succeeding by oneself through sustained effort so, the observer's belief that they too possess capabilities to overcoming (Bandura. 1994; Britner; & Pajares. 2006).

3. *Social persuasion:* it is the others' judgments which formed as feedback, praise, encouragement. Positive feedback and encouragement from influenced others (e.g. parents, teacher) can be enhanced students' perceived their efficacy. The negative feedback affects low self-efficacy and it seems also more influential to their efficacy than positive feedback (Bandura. 1994). For making positive feedback or praise effectively, should be parallel with past performance and actually ability. For example, a student who earns a C on an exam should be encouraged to aim for B+, rather than an A+, on the next exam (Rittmayer; & Beier. 2009). Moreover, given feedback should be a creative comment which tell students actual ability with suggestion and enhance them to make effort on tasks.

4. *Physiological state:* it is referred to physical, emotion, stress, anxiety. People who interpret his or her own physical state or affective will determine their perceived self-efficacy belief. The negative physical state or affective would inhibit their performing in tasks and outcomes. Moreover, the complexities of the task at hand, previous experiences in similar situations also affect the interpretation of physiological and affective states and then contribute to forming of self-efficacy (Bandura. 1994; Rittmayer, 2008; Britner; & Pajares. 2006). Some study suggested that teacher should discuss the experience of science – related anxiety with students by telling them how to control those anxieties as well as relaxation techniques (SWE-AWE-CASEE ARP. 2008: 3).

6.3 Self-efficacy in science

Self-efficacy has been used in various areas such as mathematics (Usher; & Pajares. 2009), and language (Pajares; & Johnson. 1996: 171; Raoofi; Tan; & Chan. 2012).

In science, Britner and Pajares (2006) given science self-efficacy definition as students' belief to succeed in science performance related to succeeding in science tasks and activities. It sounds like psychology index to predict how students work hard to complete the class successfully, their effort and persevere when faced with difficult science tasks, their engaging or avoiding to doing science related activities (Britner; & Pajares. 2006: 486).

In previous research, some researchers gave science tasks or activities in various terms such as students' confidence in their ability to learn course material, ability to achieve goals in the course, and ability to meet the challenge of performing well in the course (Schmidt; & Shumow. 2012: 59) and some was set the activities of science self-efficacy as students' confidence in conceptual understanding, higher-order cognitive skills, practical work, everyday application, and science communication (Lin; & Tsai. 2012: 1283 - 1284). Therefore, science tasks or an activity to measure self-efficacy is dependent on what researchers focusing on.

Summary:

Self-efficacy is defined and confirmed by many researchers in that it is a good indicator for evaluation of students' performance. As a result, it is designed to predict students' motivation; the effort includes persistence on tasks and can be used in science process skills. It is not only predicting students' performance in investigation of science but it can predict the trend of science related careers including predict how capabilities or efforts they hard which involving science and solving problems when they encounter in the future.

In this study, self – efficacy in science is defined as students' perception on their capability in terms of explaining what science lesson they have learnt, design and do scientific experiment by oneself, using the scientific knowledge they have learnt to solve problems in daily life, and present or communicate science lesson

. Moreover, this study will develop self-efficacy in science by focusing on mastery experience and also some strategies are required as follow;

1. To design science tasks and activities from easy to challenge tasks in step by step. For example, students would be perceived on their capabilities in basic science process skills at first and will be later challenged with integrated science process skills.

2. To design groups in science class with mixed abilities students because they can be a role model to each other.

3. To give feedback with creative comment to students about actually ability with suggestion and enhance them to put more effort on tasks. Positive feedback or praise effectively will be provided parallel with past performance and actual ability.

4. Students and teacher will discuss about students' anxiety related to science tasks.

6.4 The importance of self-efficacy in science

Self-efficacy in science can be used to predict students' motivation, performance, science achievement, career orientation, and choosing course-taking (Britner;& Pajares. 2006: 496. Nugent; et al. 2015, OECD. 2016: 136). Pajares (1996) indicated that students who lack confidence in skills they possess are less likely to engage in tasks and they may more quickly give up when faced with difficulty.

Previous studies stated that students with low self-efficacy in science may not exert the effort needed to complete the task and it becomes a self-fulfilling prophecy. Whereas students who have high self-efficacy in science tend to hate in some cases that more women than men often underestimate their capability, competence or skill; therefore they tried to avoided math-related courses and careers (Pajares. 1996b: 340). Moreover, most students are overconfident about their academic capabilities (Hackett; & Betz. 1989: 268; Pajares. 1996b: 339) or some study, have reported that girls perform as capable as boys in various academic tasks but having lower self-efficacy (Pajares; & Margaret. 1996: 172). Likewise, the report of PISA 2006 indicated that Thai students' science self-efficacy was higher than the average score of OECD even though their performance in science is lower than OECD average score (see Figure 9 and Figure 10). Based on the definition of self-efficacy by Bandura, PISA assessment has measured students' self-efficacy in science to be a tool to predict students' motivation in science. In PISA 2015, the definition of self-

efficacy in science was referred to future-oriented judgments about students' competency to accomplish the particular goals in a specific context which require scientific abilities (OECD. 2016).

However, Bandura indicated that some overestimation of capability is useful as it increases effort and persistence (Bandura. 1986 cited in Pajares. 1996: 339) and Bandura also argued that the stronger self-efficacy referred to the more likely person to select challenging tasks, persist at them, and perform them successfully (Pajares.1996).

Pajares (1996) stated that students should be improved in their calibration more accurately in self-perception rather than to lower students' efficacy perception or discourage their overconfidence. He also suggested that the challenged task for the teacher is to help students better understand what they know and do not know, so they can more effectively deploy appropriate cognitive strategies as they perform a task. They finally accomplish with high confidence and optimism. Similarly, Hackett & Betz (1989) also suggested that teachers should pay as much attention to students' perceptions of capability as to actual capability because that perception may more accurately predict students' motivation and future academic choices.

Summary:

Students' perception in science is important to predict their motivation and their performance, including persistence to overcome the obstacles in science learning. As a result, the researcher designed the work to find the level of self-efficacy in science and the correlation with science competencies. Therefore, the calibration should be as accurate as possible and this study will be set the approaches which improve self-efficacy accurate perceptions by focusing on mastery experience, Social persuasion, the verbal praise/feedback will focus on their efforts.

Index of self-efficacy in science

- **A** Explain why earthquakes occur more frequently in some areas than in others.
- **B** Recognise the science question that underlies a newspaper report on a health issue.
- **C** Interpret the scientific information provided on the labelling of food items.
- **D** Predict how changes to an environment will affect the survival of certain species.
- **E** Identify the science question associated with the disposal of garbage.
- **F** Describe the role of antibiotics in the treatment of disease.
- **G** Identify the better of two explanations for the formation of acid rain.
- **H** Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars.

Range between top and bottom quarter of students
Average index
Change in science performance per unit of the index
Statistically significant differences are marked in a darker tone

	Percentage of students who believe they can perform the following tasks either easily or with a bit of effort							
	A	B	C	D	E	F	G	H
Poland	76	76	82	71	62	72	71	59
United States	76	79	71	77	64	63	58	59
Canada	76	78	72	78	64	59	62	57
Jordan	73	74	76	61	75	70	63	50
Portugal	75	75	72	71	76	61	66	57
United Kingdom	75	79	69	77	67	60	61	52
Chinese Taipei	75	74	75	68	75	57	67	52
Czech Republic	81	81	61	67	60	71	57	57
Croatia	73	78	58	65	75	74	71	52
Iceland	79	72	74	72	58	63	55	59
Uruguay	71	81	72	67	64	57	66	58
Norway	78	65	66	66	68	77	76	61
Australia	78	78	68	75	61	59	54	55
Slovak Republic	76	83	77	54	61	63	67	60
Mexico	74	78	62	67	77	57	62	55
Colombia	66	69	69	70	75	60	59	49
Thailand	74	87	73	73	86	61	63	55
Hong Kong-China	70	80	65	69	72	56	75	44
Chile	75	67	71	66	60	56	65	54
Germany	83	78	61	69	62	64	64	44
Serbia	64	75	67	63	71	58	59	51
Netherlands	82	78	60	62	60	66	65	53
Estonia	71	79	71	57	69	59	54	45
Israel	66	80	67	63	65	58	49	54
Finland	83	77	68	56	63	53	48	64
Turkey	73	76	72	65	64	61	57	51
Ireland	81	68	64	63	69	55	64	41
Lithuania	80	81	68	62	68	67	53	52
OECD average	**76**	**73**	**64**	**64**	**62**	**59**	**58**	**51**
Russian Federation	68	69	75	51	70	60	49	45
Latvia	77	76	67	62	66	51	52	49
New Zealand	78	73	64	68	58	58	48	50
Montenegro	67	68	68	57	66	63	61	47
Bulgaria	66	71	68	62	72	57	45	46
Argentina	66	73	67	65	62	49	58	52
Brazil	62	76	65	67	76	54	50	42
France	79	65	67	59	52	70	43	54
Hungary	70	72	66	49	74	63	62	35
Sweden	80	67	65	67	58	53	58	54
Spain	73	61	62	59	55	54	61	56
Belgium	67	73	67	64	51	58	57	52
Denmark	78	77	70	59	54	42	49	62
Qatar	66	73	61	62	63	55	53	52
Slovenia	74	74	60	51	60	49	63	49
Macao-China	70	70	59	58	68	49	63	37
Tunisia	53	72	76	59	67	47	41	39
Austria	78	73	53	61	63	55	58	36
Liechtenstein	74	65	51	64	58	58	54	37
Greece	67	67	52	56	61	57	59	42
Luxembourg	78	71	57	65	57	58	49	44
Kyrgyzstan	61	81	68	63	62	53	48	46
Switzerland	77	69	55	62	54	52	45	41
Italy	77	70	63	64	57	46	56	46
Korea	72	68	47	53	65	55	56	39
Romania	57	68	66	52	50	46	51	37
Azerbaijan	52	65	59	53	54	45	39	37
Japan	62	64	44	58	61	33	43	26
Indonesia	43	60	43	40	61	47	28	26

FIGURE 8 The report of PISA 2006: index of self-efficacy in science

Source: OECD. (2007). PISA 2006: Science Competencies for Tomorrow's World Volume 1. Figure 3.5. p. 135.

Comparison of performance on the different scales in science

Each scale is between 0 to 9.99 score points **higher** than the combined science scale
Each scale is between 10 and 19.99 score points **higher** than the combined science scale
Each scale is 20 or more score points **higher** than the combined science scale

Each scale is between 0 to 9.99 score points **lower** than the combined science scale
Each scale is between 10 and 19.99 score points **lower** than the combined science scale
Each scale is 20 or more score points **lower** than the combined science scale

			Performance difference between the combined science scale and each scale						
			Competencies				*Knowledge of science*		
		Science score	*Identifying scientific issues*	*Explaining phenomena scientifically*	*Using scientific evidence*	*Knowledge about science*	"Earth and space"	"Living systems"	"Physical systems"
OECD	Australia	527	8.4	-6.6	4.4	6.6	3.4	-5.1	-11.8
	Austria	511	-5.7	5.6	-6.1	-7.3	-8.3	11.3	6.9
	Belgium	510	4.7	-7.7	5.6	8.3	-13.9	-7.9	-3.1
	Canada	534	-2.6	-3.6	7.1	2.8	5.8	-4.0	-5.5
	Czech Republic	513	-12.4	14.6	-12.3	-13.8	13.2	11.9	21.1
	Denmark	496	-2.6	5.4	-7.3	-3.2	-9.0	8.9	6.6
	Finland	563	-8.4	2.8	4.1	-5.6	-9.0	10.5	-3.6
	France	495	3.9	-14.1	15.8	12.2	-32.6	-5.3	-13.0
	Germany	516	-5.9	3.4	-0.3	-3.9	-5.4	8.2	0.5
	Greece	473	-4.6	3.1	-7.9	-2.5	4.0	1.3	0.8
	Hungary	504	-21.3	14.2	-6.9	-11.9	8.6	5.2	29.2
	Iceland	491	3.0	-2.7	0.2	1.7	12.1	-9.4	2.6
	Ireland	508	7.6	-2.8	-2.4	4.4	-0.2	-2.8	-3.9
	Italy	475	-1.2	4.1	-8.4	-3.6	-1.5	12.2	-3.0
	Japan	531	-9.3	-4.1	13.0	0.2	-1.1	-5.2	-1.0
	Korea	522	-3.1	-10.5	16.3	4.4	10.8	-23.9	7.6
	Luxembourg	486	-3.5	-3.1	5.5	1.9	-15.6	12.2	-12.4
	Mexico	410	11.7	-3.4	-7.4	3.3	1.9	-7.7	4.6
	Netherlands	525	7.7	-3.1	0.7	5.4	-6.8	-15.4	6.2
	New Zealand	530	5.8	-8.2	6.4	8.7	-0.8	-2.2	-14.7
	Norway	487	2.6	8.7	-14.0	-6.5	10.5	9.6	4.8
	Poland	498	-14.7	8.2	-4.1	-7.2	3.5	11.3	-0.7
	Portugal	474	12.2	-5.0	-2.1	7.1	5.1	0.7	-12.0
	Slovak Republic	488	-13.5	12.6	-10.8	-10.2	14.9	11.4	15.1
	Spain	488	0.4	1.9	-3.6	0.4	4.9	9.2	-11.6
	Sweden	503	-4.7	6.4	-7.2	-5.2	-5.5	8.4	13.7
	Switzerland	512	3.4	-3.7	7.2	2.9	-9.3	0.9	-5.1
	Turkey	424	3.7	-0.8	-6.6	1.2	1.3	1.5	-7.7
	United Kingdom	515	-1.0	1.9	-1.2	1.8	-10.2	10.6	-6.4
	United States	489	3.2	-2.8	-0.4	3.3	15.1	-2.1	-3.7
Partners	Argentina	391	4.1	-4.8	-5.8	5.9	-7.5	-0.2	-7.8
	Azerbaijan	382	-29.6	29.6	-38.1	-27.2	17.9	15.2	50.5
	Brazil	390	7.8	-0.1	-12.2	3.3	-15.4	12.6	-5.5
	Bulgaria	434	-6.8	10.2	-17.4	-8.5	9.1	11.1	1.6
	Chile	438	5.9	-6.1	1.4	4.5	-9.9	-3.8	-5.0
	Colombia	388	14.4	-9.0	-4.9	8.4	-17.7	-4.5	-10.0
	Croatia	493	0.3	-0.8	-2.9	0.9	4.0	4.5	-0.4
	Estonia	531	-15.7	9.2	-0.4	-8.4	9.0	8.4	3.6
	Hong Kong-China	542	-14.4	7.0	0.2	-0.6	-17.1	15.4	3.3
	Indonesia	393	-0.4	1.1	-7.8	-6.4	8.3	-2.5	-7.4
	Israel	454	3.1	-10.5	6.4	12.5	-36.9	4.5	-11.3
	Jordan	422	-13.1	15.7	-17.4	-13.5	-1.3	28.1	10.9
	Kyrgyzstan	322	-0.7	11.7	-34.0	-13.5	-7.0	7.7	27.3
	Latvia	490	-0.9	-3.2	1.1	1.6	4.3	-8.2	5.1
	Liechtenstein	522	0.1	-6.0	12.7	4.2	-9.4	1.7	-7.1
	Lithuania	488	-11.9	6.5	-1.4	-5.6	-1.4	14.7	2.0
	Macao-China	511	-20.8	9.2	0.7	-5.9	-4.9	14.2	6.7
	Montenegro	412	-10.7	4.9	-5.2	-4.8	-0.4	18.2	-4.5
	Qatar	349	3.1	6.6	-25.5	-6.2	0.3	11.7	8.4
	Romania	418	-8.9	7.4	-10.9	-5.6	-11.5	7.8	10.3
	Russian Federation	479	-16.6	3.8	1.4	-4.5	2.0	10.5	-0.2
	Serbia	436	-5.1	5.2	-10.8	-5.1	4.9	13.9	-0.3
	Slovenia	519	-1.8	4.0	-2.8	-8.7	14.7	-2.2	12.1
	Chinese Taipei	532	-23.8	12.7	-0.6	-7.0	-3.2	16.9	13.0
	Thailand	421	-7.8	-1.1	2.1	0.2	8.9	10.7	-13.7
	Tunisia	386	-1.7	-2.2	-3.6	3.8	-33.4	6.2	7.3
	Uruguay	428	0.5	-5.2	0.9	3.4	-31.2	4.5	-6.7

FIGURE 9 The report of PISA 2006: the comparison of performance on the difference scales in science

Source: OECD. (2007). PISA 2006: Science Competencies for Tomorrow's World Volume 1. Figure 2.13. p. 63.

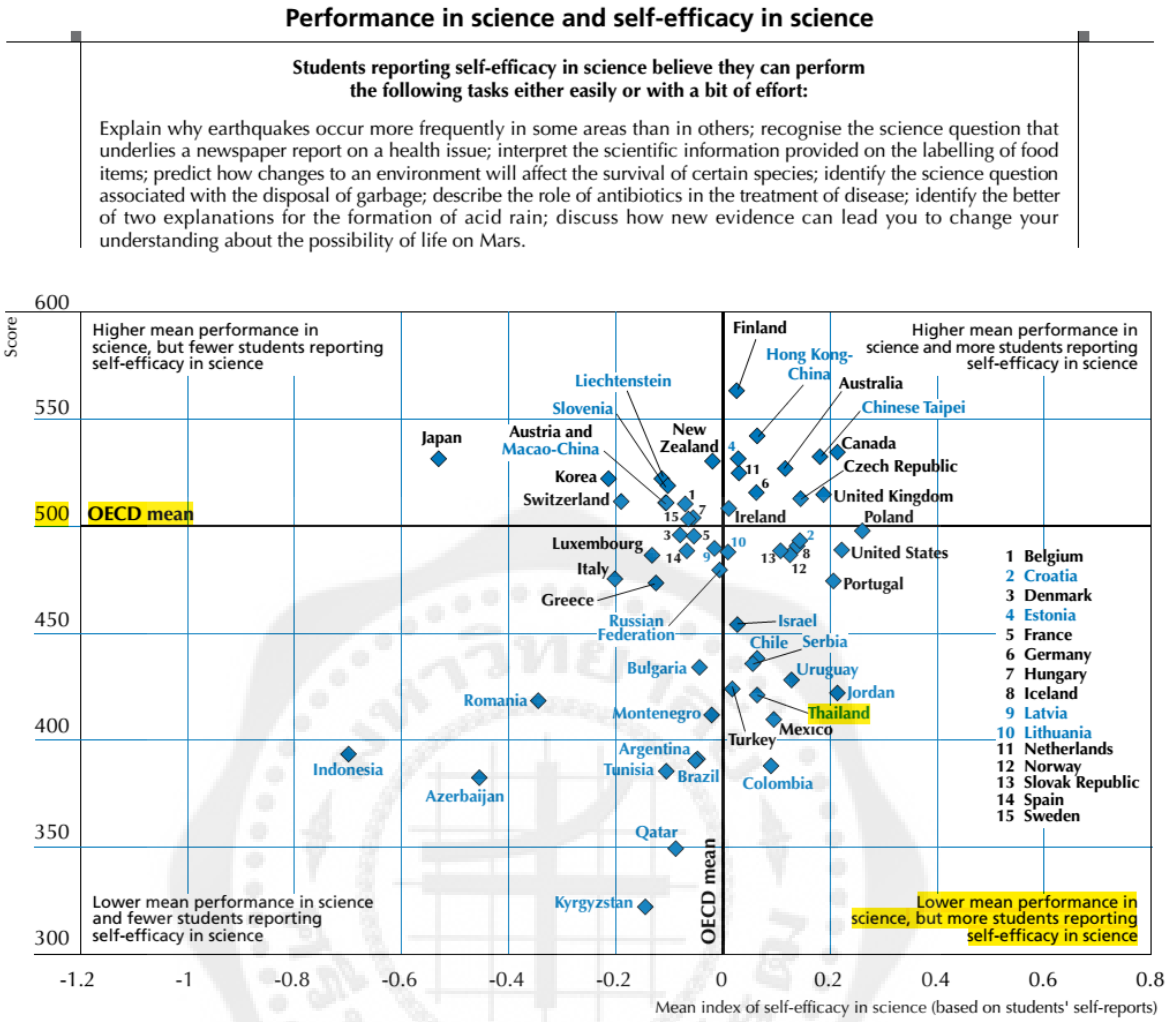

FIGURE 10 Performance in science and self-efficacy in science

Source: OECD. (2007). PISA 2006: Science Competencies for Tomorrow's World Volume 1. Figure 2.13. p. 136.

6.6 Assessment of self-efficacy in science

Perceived efficacy plays a key role in human functions because it affects behavior both directly and impact on other determinants such as goals and aspirations, outcome expectations, affective proclivities, and perception of impediments and opportunities in the social environment (Bandura. 2000: 75). As it influences to how much effort they put in the given endeavors, the outcomes they expect on their efforts to produce, how long they persevere when faced with obstacles, the quality of their emotional life and how much

stress and depression they experienced, and the life choices they make and accomplishment they realize (Bandura. 2006: 309).

In the standard methodology, to measure self-efficacy beliefs, individuals are presented with items portraying different levels of task demands and they rate the strength of their belief in their ability to execute the requisite activities (Bandura. 2006). The assessment of general academic self-perceptions of competence, the basic problem with such assessment is that students must generate these judgments without a clear academic activity or task in mind. As a result, they generate the judgment by some fashion mentally aggregating related perceptions that they hope will be related to imagined tasks. Consequently, the domain-specific assessment is raised. It is more explanatory and predictive than omnibus measures and preferable to general academic judgment because it is created questions with specific task such as asking students to provide their confidence to solve mathematics problem or writing skills (the example questions are shown in Table 9)

Although, it is more preferable but still deficient because scientific, mathematics, linguistic, literary and artistic academic subdomains differ remarkably in types of competencies they require. By details of specific assessment efficacy recommendation from Bandura, using multiple items relate different facets of the same academic subject such as "I am confident about my ability to do the work in this class" and "I am confident I can perform as well or better than other in this class". Then students rate the strength of their belief in their ability to execute the requisite activities. (See Table 8)

Furthermore, if the purpose of a study is to achieve explanatory and predictive power especially to establish causal relations between beliefs and outcomes, self-efficacy judgments should be consistent and tailored to the domain of function and/or task. For example, the studies which have operationalized mathematics self-efficacy as students' judgment of their capability to solve math problems, perform math-related tasks, and succeed in math-related courses so, the mathematics self-efficacy must consist of three subscales for judgment capabilities. Therefore, students' confidence to solve mathematics problems is a more powerful predictor of their ability to solve those problems than their confidence to perform math-related tasks or their confidence to earn high marks in math-related course (Pajares. 1996c).

Note that the skills required to accomplish the criteria task should be clear to the participant because to judge the capability requires knowledge of task demands. If students do not know what demands must be fulfilled in given endeavor, they cannot accurately judge whether he/she has the requisite capabilities to do so. Finally note the level of specificity of an efficacy assessment should depend on the complexity of the performance criteria with which is compared. In other words, to judge competence need not be so microscopically operationalized that the assessment loses all sense of practical utility (Pajares. 1996c). But the criteria task is important: if the criteria task should be a particularly relevant one such as choice of intention to enroll in science-related courses, self-efficacy can be tailored to these levels and still remain highly predictive. Some studies compared students' confidence with more than one criteria task such as the study of students' confidence to succeed in math-related courses with three career-related outcomes (Lent; Lopez; & Bieschke. 1993) or compared with five dimensions for judging students' confidence in science learning (Lin; & Tsai. 2012). As criterial task affects to the results of self-efficacy assessment so, Bandura have suggested that characteristic of criterial task in assessing should be; take place in close temporal proximity, encompass the full range of criteria task, specificity and correspondence, items be phased in terms of "can" rather than "will", and items be phased in term of can "now" rather than can "later" (Pajares. 1996c). More conditions on specificity of judgment are shown in Figure 11, 12

The scale of strength efficacy beliefs on a 100-point scale, ranging in 10 unit intervals from 0 ("Cannot do"); through intermediate degrees of assurance, 50 ("Moderately certain can do"); to complete assurance, 100 ("Highly certain can do"). The instructions and standard response format are given below (Bandura. 2006).

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Highly certain can do

Suggestion, scale that use only a few steps should be avoided because they are less sensitive and less reliable. In other words, people usually avoid the extreme position so a

scale with only a few steps may, in actual use, shrink to one or two points. Including too few steps loses differentiation information because people who use the same response category may differ if intermediate steps were included (Bandura. 2006). Likewise the identified of Pajares; Harley; & Valentine (2001) that an efficacy scale with 0-100 response format is a stronger predictor of performance than one with a 5-interval scale. However, many studies of science self-efficacy assessment have not used 0-100 response format but using the scale with a 5-interval scale: strongly agree, agree, somewhat agree and somewhat disagree, disagree, and strongly disagree (Baldwin; Ebert-May; & Burns. 1999; OECD. 2007; Lin; & Tsai. 2012) and A 9-point scale was chosen for the response format, where 1 corresponded to very poorly and 9 corresponded to very well. A higher score on this scale indicated higher self-efficacy in chemistry (Uzuntiryjaki; Capa. 2009).

Summary:

There are ways to construct and assess specificity of self-efficacy. However, the previous research on students' self-efficacy in science is not often seen this might be insufficient to fully understand in students' learning science. Consequently, this study is focusing on students' perception their capability in science in terms of explaining what science lesson they have learnt, design and do scientific experiment by oneself, using the scientific knowledge they have learnt to solve problems in daily life, and present or communicate science lesson. As the study will be conducted in seventh grade students, self-efficacy test is developed by researcher which a 5-point scale is chosen for the response format.

TABLE 7 Items used measure various self-efficacy constructs

Source	Sample question or direction	Answer options
Collective efficacy (Bandura, 1993)	Please indicate your confidence that you attain the following grade level gains with the students in your class this year. [gain in 2-month increments presented]	0 (no confidence at all) to 10 (certain I can do), in intervals of 1
Self-efficacy for performance of division problems (Schunk, 1981)	[Division problem shown for 2 seconds] Circle the number on the line that matches how sure you are that you could work problems like those shown and get the right answers.	10 (not sure) to 100 (really sure), in intervals of 10
Self-efficacy for reading tasks (Shell et al., 1995)	How confident are you that you can perform each of the following reading tasks? [18 tasks presented—e.g., "read a letter from a friend"]	1 (I'm sure I can) to 5 (I'm sure I can't), in intervals of 1
Self-efficacy for academic achievement (Bandura, 1989)	How well can you…? [completed by 9 academic domain—e.g., "learn general mathematics, learn reading and writing language skills"]	0 (not well at all) to 7 (very well), in intervals of 1
Self-efficacy for learning (Schunk, 1996)	[Students are presented with sample mathematics problems or reading/writing tasks for a brief time. They are asked to provide a confidence judgment to correctly solve the problems, perform paragraph writing tasks etc.]	10 (not sure) to 100 (really sure), in intervals of 10

ON CORRESPONDENCE BETWEEN JUDGMENT AND OUTCOME

Self-efficacy Should be Consistent with and Tailored to the Performance Outcome With Which it is Compared - To achieve explanatory and predictive power, efficacy measures must be tailored to domains of functioning and represent gradations of task demands within those domains. Causal processes are best clarified by microanalytic measures of efficacy beliefs tailored to the domain of functioning being explored.

Capabilities Assessed and Tested Should Match - The structure of the relation between efficacy beliefs and action requires that both events tap similar capabilities.

Skills Required to Accomplish the Criterial Task Should be Clear to the Participant - Judgments of self-efficacy require knowledge of task demands. If one does not know what demands must be fulfilled in a given endeavor, one cannot accurately judge whether one has the requisite capabilities to do so.

When Criterial Task is Unknown, Self-efficacy Assessment with Generalized Measure Results in Loss of Predictive Power - When the situations people are likely to encounter are not fully known, one would do better predicting from perceived efficacy for common than for unusual situational demands. It should be noted, however, that efficacy predictiveness for common conditions is gained at the loss of some predictiveness for conditions within the same general context that have fewer common features.

Adapted from Albert Bandura (in press)
Self-Efficacy: The Exercise of Control

ASSESSING SELF-EFFICACY AND CRITERIAL TASK

High-stakes Assessments are Preferable - Individuals may possess the requisite skills and a strong sense of efficacy that they can execute them well, but choose not to perform the activities because they have no incentive to do so. Situations in which misjudgments of capabilities carry no consequences provide little incentive for serious appraisal of personal efficacy

Assessments Should Take Place in Close Temporal Proximity - The existing relation between efficacy beliefs and action is most accurately revealed when they are measured in close temporal proximity. The closer in time the better the test for causation.

Self-efficacy Assessment Should Encompass the Full Range of Criterial Task - Self-efficacy theory is often tested not on a completely unfounded factor, but on one that exerts only partial influence over the behavior of interest.

Specificity and Correspondence - Causal processes are best clarified by microanalytic measures of self-efficacy beliefs that are tailored to the domain of functioning being explored.

Items Should be Phrased in Terms of *Can* rather than *Will* - The items are phrased in terms of *can* rather than *will*. Can is a judgment of capability; will is a statement of intention.

Items Should be Phrased in Terms of *Can Now* rather than *Can Later* - People are asked to judge their operative capabilities as of now not their potential capabilities or their expected future capabilities.

Adapted from Albert Bandura (in press)
Self-Efficacy: The Exercise of Control

FIGURE 11 Note of constructing self-efficacy assessment

Source: Pajares, Frank. (1996c). Assessing self-efficacy beliefs and academic outcomes: The case for specificity and correspondence. Table 1. p. 13- 16.

ON SPECIFICITY OF JUDGMENT

Omnibus Measures are Problematic - Omnibus measures create problems of predictive relevance as well as obscurity about what is being assessed.

General Academic Judgments are Problematic - When an academic domain is unspecified, students have to come up with a single judgment of their capabilities from the scholastic activity that happens to spring to mind at the moment, guess about the scholastic activity the assessor had in mind, or engage in subjective weighting and aggregation across diverse subject matters.

Domain-specific Judgments are Preferable to Generalized Judgments but Inferior to Task-specific Judgments - A self-efficacy measure cast in terms of a general academic domain is more explanatory and predictive than an omnibus measure but still deficient because scientific, mathematics, linguistic, literary and artistic academic subdomains differ markedly in the types of competencies they require.

Academic Domain-specific Assessments Using Multiple Items Restating Different Facets of the Same Domain are Problematic - Items that measure perceived self-efficacy for different facets of the same domain cannot be treated as equivalent. Restricting items to those that correlate highly with each other may produce a self-efficacy scale that measures redundantly only a segment of the intended domain, and a narrow range of the segment at that.

Particularized Judgments are the Most Predictive Assessments - Efficacy beliefs should be measured in terms of particularized judgments of capability that may vary across realms of activity, different levels of task demands within a given activity domain, and under different situational circumstances. Major progress in understanding how personal factors operate in causal structures requires explicit measurement of the particular personal determinants that are germane to given spheres of functioning.

Particularized Level of Generality Should be Determined by the Nature of the Criterial Task - Self-efficacy is commonly misconstrued as concerned solely with "specific behaviors in specific situations." Domain particularity need not mean behavioral specificity. Efficacy beliefs are multifaceted and contextual, but the level of generality of the efficacy items within a given domain of functioning varies depending on the degree of situational resemblance and foreseeability of task demands. *Bur regardless of the level of generality, in no case are the efficacy items disembodied from contexts and level of task demands.*

Adapted from Albert Bandura (in press)
Self-Efficacy: The Exercise of Control

FIGURE 12 Note of constructing self-efficacy on correspondence between judgment and outcome

Source: Pajares, Frank. (1996c). Assessing self-efficacy beliefs and academic outcomes: The case for specificity and correspondence. Table 1. p. 14.

7. Science competency

Competency refers to a description of a particular mental ability or skill students are expected to learn. There are three main competencies required for evaluating students' science literacy in PISA 2015 framework by details are shown below (OECD. 2013: 14 - 17);

Competence 1: Explain phenomena scientifically

Recognize, offer and evaluate explanations for a range of natural and technological phenomena demonstrating the ability to: Recall and apply appropriate scientific knowledge; Identify, use and generate explanatory models and representations; Make and justify appropriate predictions; Offer explanatory hypotheses; Explain the potential implications of scientific knowledge for society.

Competence 2: Evaluate and design scientific enquiry

Describe and appraise scientific investigations and propose ways of addressing questions scientifically demonstrating the ability to: Identify the question explored in a given scientific study; Distinguish questions that are possible to investigate scientifically; Propose a way of exploring a given question scientifically; Evaluate ways of exploring a given question scientifically; Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations.

Competence 3: Interpret data and evidence scientifically

Analyze and evaluate scientific data, claims and arguments in a variety of representations and draw appropriate conclusions demonstrating the ability to: Transform data from one representation to another; Analyze and interpret data and draw appropriate conclusions; Identify the assumptions, evidence and reasoning in science-related texts; Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations; Evaluate scientific arguments and evidence from different sources (*e.g.* newspaper, internet, journals)

7.1 Assessment of science competence

To assess students' science literacy, the PISA 2015 framework has categorized six levels of science competencies for evaluating. The six levels of competencies are shown in Table 8.

TABLE 8 Initial draft reporting scale proposed for PISA 2015

level	Descriptor
6	At Level 6, students are able to use content, procedural and epistemic knowledge to consistently provide explanations, evaluate and design scientific enquiries and interpret data in a variety of complex life situations that require a high level of cognitive demand. They can draw appropriate inferences from a range of different complex data sources, in a variety of contexts and provide explanations of multi-step causal relationships. They can consistently distinguish scientific and non-scientific questions, explain the purposes of enquiry, and control relevant variables in a given scientific enquiry or any experimental design of their own. They can transform data representations, interpret complex data and demonstrate an ability to make appropriate judgments about the reliability and accuracy of any scientific claims. Level 6 students consistently demonstrate advanced scientific thinking and reasoning requiring the use of models and abstract ideas and use such reasoning in unfamiliar and complex situations. They can develop arguments to critique and evaluate explanations, models, interpretations of data and proposed experimental designs in a range of personal, local and global contexts.
5	At Level 5, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a variety of life situations in some but not all cases of high cognitive demand. They draw inferences from complex data sources, in a variety of contexts and can explain some multi-step causal relationships. Generally, they can distinguish scientific and non-scientific questions, explain the purposes of enquiry, and control relevant variables in a given scientific enquiry or any experimental design of their own. They can transform some data representations, interpret complex data and demonstrate an ability to make appropriate judgments about the reliability and accuracy of any scientific claims. Level 5 students show evidence of advanced scientific thinking and reasoning requiring the use of models and abstract ideas and use such reasoning in unfamiliar and complex situations. They can develop arguments to critique and evaluate explanations, models, interpretations of data and proposed experimental designs in some but not all personal, local and global contexts.
4	At Level 4, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a variety of given life situations that require mostly a medium level of cognitive demand. They can draw inferences from different data sources, in a variety of contexts and can explain causal

TABLE 8 (continued)

level	Descriptor
4	relationships. They can distinguish scientific and non-scientific questions, and control variables in some but not all scientific enquiry or in an experimental design of their own. They can transform and interpret data and have some understanding about the confidence held about any scientific claims. Level 4 students show evidence of linked scientific thinking and reasoning and can apply this to unfamiliar situations. Students can also develop simple arguments to question and critically analyze explanations, models, interpretations of data and proposed experimental designs in some personal, local and global contexts.
3	At Level 3, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in some given life situations that require at most a medium level of cognitive demand. They are able to draw a few inferences from different data sources, in a variety of contexts, and can describe and partially explain simple causal relationships. They can distinguish some scientific and nonscientific questions, and control some variables in a given scientific enquiry or in an experimental design of their own. They can transform and interpret simple data and are able to comment on the confidence of scientific claims. Level 3 students show some evidence of linked scientific thinking and reasoning, usually applied to familiar situations. Students can develop partial arguments to question and critically analyze explanations, models, interpretations of data and proposed experimental designs in some personal, local and global contexts.
2	At Level 2, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in some given familiar life situations that require mostly a low level of cognitive demand. They are able to make a few inferences from different sources of data, in few contexts, and can describe simple causal relationships. They can distinguish some simple scientific and non-scientific questions, and distinguish between independent and dependent variables in a given scientific enquiry or in a simple experimental design of their own. They can transform and describe simple data, identify straightforward errors, and make some valid comments on the trustworthiness of scientific claims. Students can develop partial arguments to question and comment on the merits of competing explanations, interpretations of data and proposed experimental designs in some personal, local and global contexts.

TABLE 8 (continued)

level	Descriptor
1a	At Level 1a, students are able to use a little content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a few familiar life situations that require a low level of cognitive demand. They are able to use a few simple sources of data, in a few contexts and can describe some very simple causal relationships. They can distinguish some simple scientific and non-scientific questions, and identify the independent variable in a given scientific enquiry or in a simple experimental design of their own. They can partially transform and describe simple data and apply them directly to a few familiar situations. Students can comment on the merits of competing explanations, interpretations of data and proposed experimental designs in some very familiar personal, local and global contexts.
1b	At Level 1b, students demonstrate a little evidence to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a few familiar life situations that require a low level of cognitive demand. They are able to identify straightforward patterns in simple sources of data in a few familiar contexts and can offer attempts at describing simple causal relationships. They can identify the independent variable in a given scientific enquiry or in a simple design of their own. They attempt to transform and describe simple data and apply them directly to a few familiar situations

Source: OECD. 2013. PISA 2015 Draft science framework. Figure 27. p. 48 - 49.

***[Note: Currently these descriptors should be seen as a hypothesis. When the field trials have been conducted, the data will enable these descriptions to be refined]*

As the scale of science competencies assessment has mentioned about the levels of cognitive demand namely low, medium, and high which will be required for evaluating, the details of each item is given meaning as follow (OECD. 2013: 42):

Low (L) – Carry out a one-step procedure, for example recall of a fact, term, principle or concept or locating a single point of information from a graph or table.

Medium (M) – Use and application of conceptual knowledge to describe or explain phenomena, select appropriate procedures involving two or more steps, organize/ display data, interpret or use simple data sets or graphs.

High (H) – Analyze complex information or data, synthesis or evaluate evidence, justify, reason given various sources, develop a plan or sequence of steps to approach a problem.

Summary:

These competencies in PISA 2015; explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically will be adapted to be a science competencies assessment in this study. Although, the review literature showed six level scales of science competencies assessment but researcher chose only three main level to evaluate students' performance by observation while students doing the learning activities such as doing the experiment, react in the class and discussion.

Based on all review the literature. It could be the framework below;

Theoretical framework

According to the learning model development based on the problems found in science classroom, students lack science process skills and have less concern/awareness while learning. Additionally, researcher has found that lacking of science process skills and having less concern/awareness while learning might affect to students' achievement on science literacy as the science process skills are a part of PISA 2006 framework and in the procedural knowledge of PISA 2015 framework. Moreover, the PISA 2006 report showed Thai students' achievement on science literacy (which was measured through three science competencies) had not consistent with their perceived in capabilities (self-efficacy in science); low mean score of achievement but high level of self-efficacy in science. It could be concluded that three problems are needed to be solved; namely lacking science process skills and having less concern/awareness while learning, low achievement on

science literacy, and the correlation between science self-efficacy and science literacy achievement.

Therefore, those problems addressed lead to develop the metacognitive strategies embedded in inquiry learning model which was infused between 5E inquiries and metacognition in terms of regulation of cognition (or metacognitive strategies). The regulation of cognition consists of planning (P), monitoring (M), and evaluating (E) and these become the sub-step cycle in the 5E phases model. The sub-step cycle is driving in four phases of 5E model, namely engagement-P-M-E, exploration-P-M-E, explanation-P-M-E, elaboration-P-M-E, and evaluation phase. The details related to each component are described as following;

The 5E instructional learning model

The 5Es Instructional Model is developed by Science Curriculum Study (BSCS) consisting of five phases; engagement, exploration, explanation, elaboration, and evaluation. The details are summarized as following (Bybee; et al. 2006):

(1) *Engagement* - to access the learners' prior knowledge and help them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge.

(2) *Exploration* – to provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Students may complete lab activities to generate new ideas.

(3) *Explanation*- to provide students opportunities to demonstrate their conceptual understanding, process skills, or behaviors. Teachers also directly introduce a concept, process, or skill. An explanation from the teacher or the curriculum may guide them toward a deeper understanding.

(4) *Elaboration* - to provide task students in order to apply or extend conceptual understanding and skills through new experiences.

(5) *Evaluation* - to assess understanding and abilities by themselves and teachers can evaluate student progress toward the learning objectives.

The 5Es Instructional Model is familiar to Thai teachers.

Inquiry-based learning

Inquiry is an active learning process which engages students learning with meaningful (NSES cited in Anderson. 2002; Barrow. 2006: 266). It refers to the ways which scientists study the natural world and propose explanations based on the evidence derived from their work, the activities of students develop knowledge and understanding of scientific ideas and understanding of how scientists study the natural world (National Research Council. 1996: 23). Inquiry teaching and learning have five essential features: engaging in scientifically oriented questions, giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific knowledge, and communicating and justifying explanations. Its characterize processes are multifaceted activities; observation, posing questions, investigation, using tools to gather and analyze, explanation, and communicating results. Therefore, inquiry leads students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories.

Previous studies showed inquiry learning improve students' science process skills (Şimşek; &KabapÕnar. 2010; Koksala; &Berberoglu. 2012; Lati.;Supasorn; Promarak. 2012; Yadav; & Mishra. 2013; Aydoğdua; Buldur; & Kartal. 2013; Ogan-Bekiroğlu; & Arslan. 2014; Chairam; Klahan; & Coll. 2015). Since inquiry learning processes require students to use science process skills and students have to plan and understand the processes in order to accomplish the investigation, Schraw and et al. (2006) stated that metacognitive strategies can foster inquiry instructional in terms of expressing explicit planning, monitoring, and evaluating especially authentic inquiry can be promoted by metacognitive strategies. It stimulates students' active engagement in learning process in terms of using metacognitive strategies to monitor their understanding.

Consequently, inquiry learning is infused by explicit step of planning-monitoring-evaluating which aim to enhance more clearly learning process to solve their less concern while learning. As a result, students learn through the explicit step of planning-monitoring-evaluating in 5E inquiry cycle. Finally, the explicit step of planning-monitoring-evaluating is infused since engagement phase (E1) until elaboration phase (E4). However, it is not infused in the evaluation phase (E5) because this phase aims to evaluate process and product of learning.

Metacognition

The definition of metacognition is proposed by many researchers; however it consists of two main parts: metacognitive knowledge and cognitive regulation.

Schraw and et al. (1994; 1995; 2006) have defined the metacognition in science education as the ability to reflect upon, understand, and control one's learning which is consisted of two main components; 1) knowledge of cognition refers to what individuals know about their cognition and includes three subcomponents: declarative, procedural, and conditional knowledge which are referred to know about oneself or task, know how to deal with or choosing the strategy, and know when or why certain strategies have to be used, respectively, and 2) knowledge about regulation of cognition refers toa set of activities that help students to control their learning. It consists of three components, namely planning, monitoring, and evaluating.

Metacognitive skills lead students set the learning goals, manage the learning environment by themselves and to apply strategies effectively to study. Moreover, it enables students to choose and make proper use of study strategies, then become conscious and controllable activities (Pressley; et al. 1983 cited in Cera; Mancini;&Antonietti. 2013)

Self-efficacy

Self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance (Bandura. 1994: 2; 2006: 309). It influences to outcomes of motivation (Bandura. 1994: 4; Zimmerman. 2000: 82; Bong; &Skaalvik. 2003: 10), self-regulatory processes (Bandura. 1994: 4; Zimmerman. 2000: 87), emotion (Bandura, A. 1994: 2; Bong , M; &Skaalvik. 2003: 10), cognitive, and academic achievement (Bong; &Skaalvik. 2003: 10;) such as science achievement and performance (Britner; &Pajares. 2006; OECD. 2007: 136; Nugent; et al. 2015).

Britner and Pajares (2006) define science self-efficacy as students' belief to succeed in science performance related to succeeding in science tasks and activities. It predicts how students work hard to complete the class successfully, their effort and persevere when faced with difficult science tasks, their engaging or avoiding to doing

science related activities (Britner; &Pajares. 2006: 486). PISA assessment has measured students' self-efficacy in science to be a tool to predict students' motivation in science.

The level of self-efficacy can develop by four sources including mastery experience related to accomplish or failure experience, vicarious experience related to others performing task/ role model, physiological state related to physical, emotion, stress, anxiety, and social persuasion related to feedback from others. Moreover, this study includes students' monitoring and evaluating their performances while doing whole class discussion as persuasion. The most influential source is mastery experience that can be developed by authentic inquiry-oriented science investigations especially during middle school provide mastery experience necessary to develop strong science self-efficacy beliefs (Britner;&Pajares. 2006).

Furthermore, certain studies suggested that metacognitive skills help to develop a greater sense of self-efficacy (Cera; Mancini;& Antonietti. 2013: p. 133-134). Meanwhile, the research work showed that self-efficacy has relationship with metacognitive skills; strong self-efficacy leads students use more metacognitive skills in learning (Stanton; et al. 2015: 1510); if they believe they cannot do it or have to work harder. It then leads them give up.

On the other hand, lack of metacognitive knowledge leads students cannot accurately judge what they know and, more importantly what they do not know then overestimate their performance. If students believe they have mastered concepts, it may lead them to underprepare for an exam (Stanton; et al. 2015: 155).

Science process skills

A Process Approach (SAPA) which was established by the American Association for the Advancement of Science (AAAS) defines science process skills as a set of broadly transferable abilities to carry out in many science disciplines and reflective of the working process of scientists. The SAPA has categorized process skills into eight basic and five integrated processes. The basic science process skills (BSPS) include observing, classifying, using numbers, measuring, space/time relationships, communicating, predicting, and inferring. The integrated science process skills (ISPS) which is more complex include

defining operationally, formulating hypotheses, interpreting data, controlling variables, and experimenting (Sanderson&Kratochvil. 1971: 34; Padilla.1990; Sheeba. 2013).

Science process skills is called as the core skills for learning science (Sheeba. 2013; Harlen.1999) and the development of scientific process skills has to be a major goal of science education. At present, it is acknowledged in curriculum statements worldwide (Harlen. 1999). It provides students to investigate the evidence to conclusion and emerging of scientific knowledge. Mastery of science process skills enables students to understand, at a much deeper level, expansion their concepts (small idea) to explain the phenomena (big idea) reasonably (Harlen. 1999; Keil; Haney;&Zoffel. 2009). Previous studies have shown positive correlation between science process skills and science achievement (Ong Saw Lan. 2006; Aydogdu. 2007). However, it was found no correlation in the study of R.Gokul Raj & S.Nirmala Devi (2014). Moreover, no study showed the correlation between science process skills and science competencies, therefore; this study aims to study its correlation.

Science competencies

Referred to science literacy of PISA 2015 framework, competency is defined as a description of a particular mental ability or skill students are expected to learn which are included three main competencies required to evaluate students' science literacy; 1) Explain phenomena scientifically, 2) Evaluate and design scientific enquiry, and 3) Interpret data and evidence scientifically (OECD. 2013: 14 - 17). Additionally, PISA 2006 and PISA 2015, the year focusing on science literacy measurement calculated the correlation between self-efficacy in science and science literacy achievement. Those reports of PISA revealed that Thai students' means score of self-efficacy in science had no correlation with science literacy achievement (OECD. 2007: 135; OECD. 2016; 137-140); low mean scores of achievement but high level of self-efficacy in science. It is weakly predicable on students' motivation on science. Thus, this study using the learning model aims to adjust the consistency between students' self-efficacy in science and their performance as well and then calculated its correlations is conducted.

Based on review, the theoretical framework of this study is showed in Figure 13.

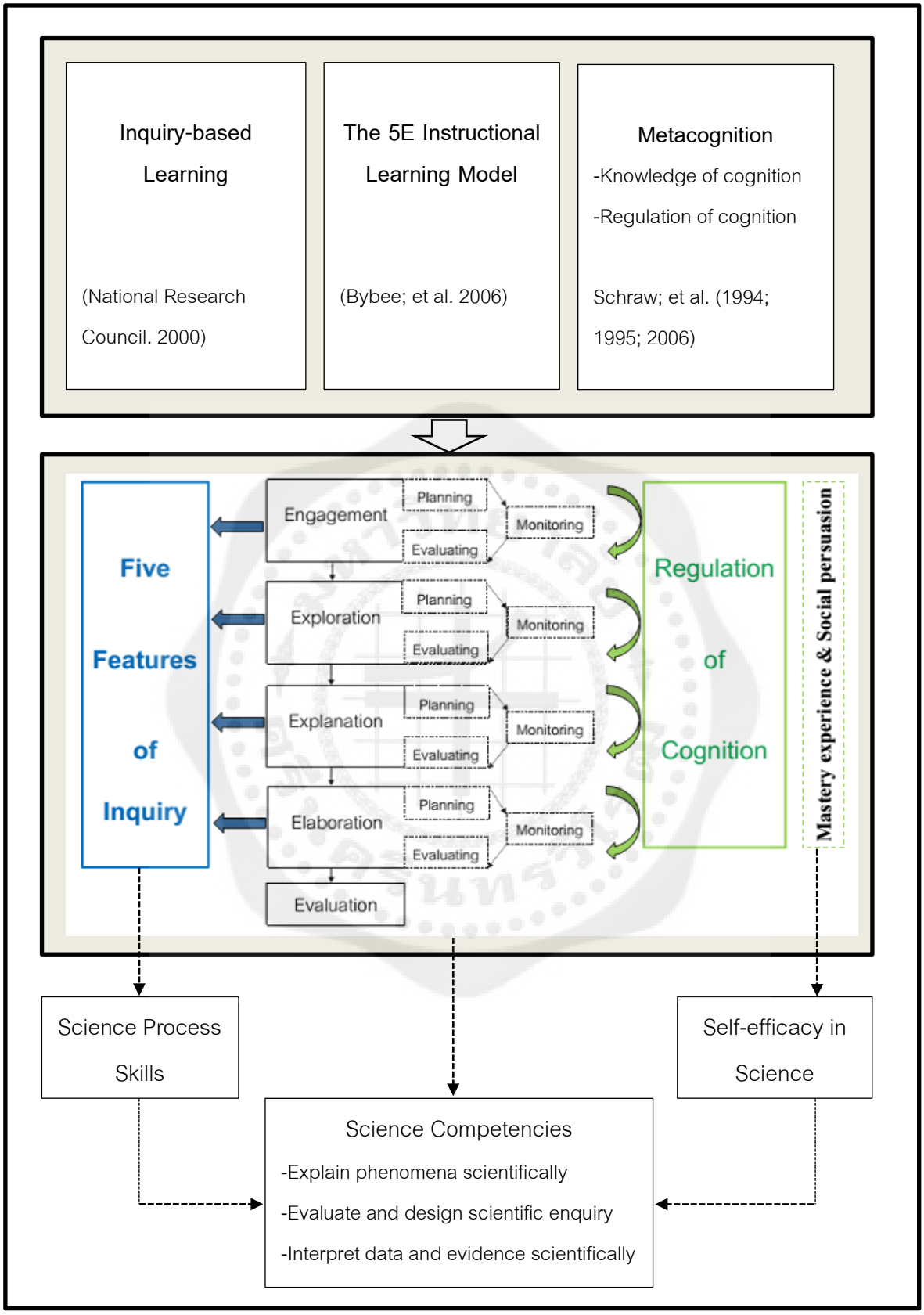

FIGURE 13 Theoretical framework

CHAPTER 3
METHODOLOGY

This chapter described the details of research methodology which present the stages of development and the evaluating metacognition strategy embedded in inquiry learning model. This study was conducted by following these processes:

Stage 1: Preparation

1.1 Teachers' opinions related science classroom problem

1.1.1 Research methodology

1.1.2 Population and participants

1.1.3 Research instrument and data collection

1.1.4 Data analysis

1.2 An exploration of students' level of science process skills

1.2.1 Research methodology

1.2.2 Population and participants

1.2.3 Research instrument and data collection

1.2.4 Data analysis

Stage 2: Development of learning model and research instruments

2.1 Developing the metacognition strategy embedded in inquiry learning model

2.2 Developing research instruments

2.3 Developing the lesson plans and instructional materials

2.4 Conducting a pilot study

Stage 3: Evaluation the effectiveness of the learning model

3.1 Research methodology

3.2 Population and participants

3.3 Research instrument and data collection

3.4 Data Analysis

This study consists of three stages: preparation, development of learning model and research instruments, and evaluation the effectiveness of the learning model stage. By details of each stage is summarized in the Figure 14.

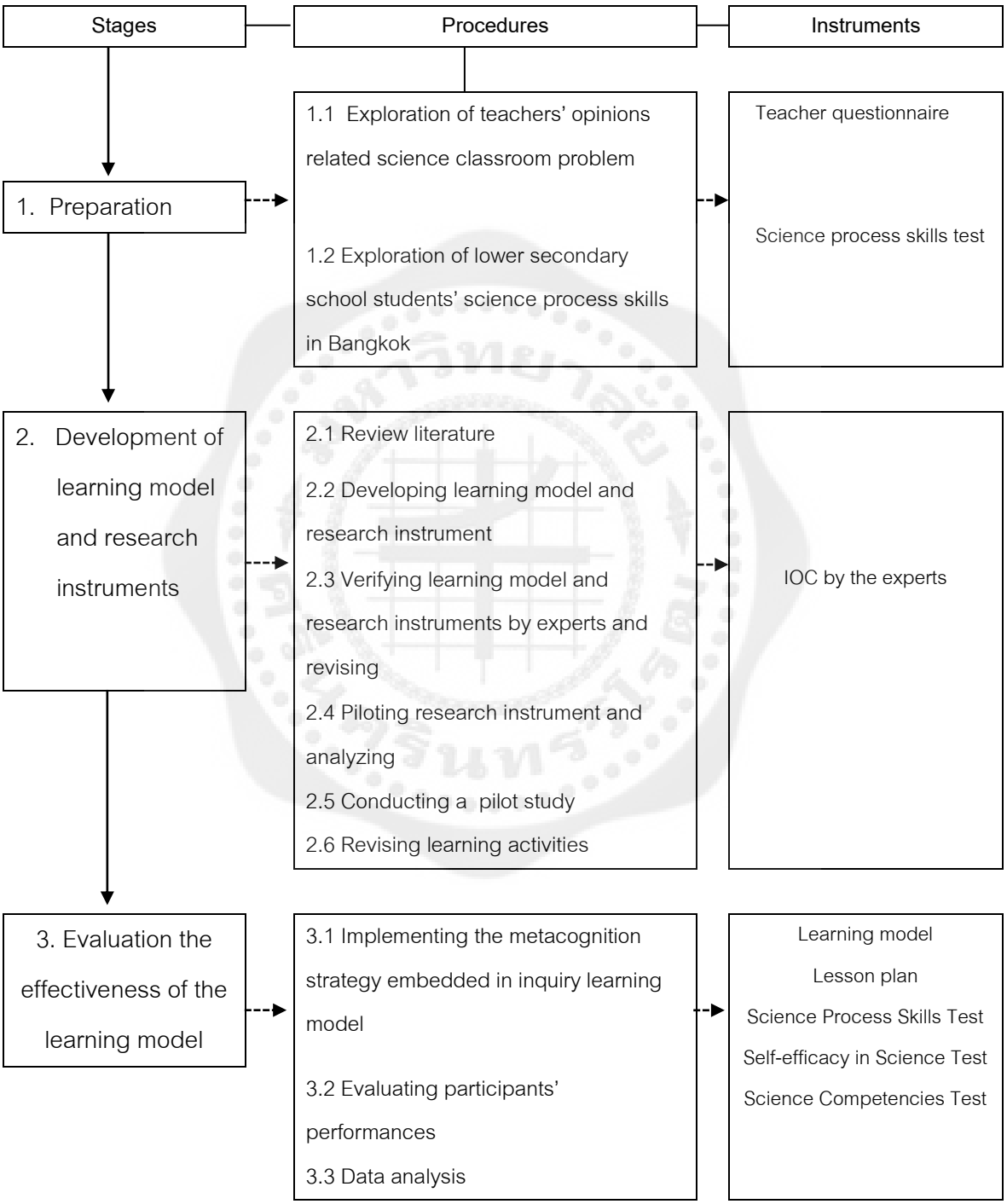

FIGURE 14 Overview of the study

Stage 1: Preparation

1.1 Exploration of teachers' opinions related science classroom problems

According to the OECD, Thai students were placed at below the mean scores of the PISA measurement (OECD. 2007). Moreover, the Ordinary National Educational Test (O-NET) which evaluated the quality of education at the national level based on the Basic Education Core Curriculum B.E. 2551 (A.D. 2008) indicated that grade nine Thai students' mean scores in science were placed among the lowest among the other subjects. The results of science mean scores of Thai students during the year B.E. 2554-2556 were; 32.19, 35.37, and 37.95 respectively (National Institute of Educational Teaching Service. 2013). To solve problem of Thai students' achievement, the context of science learning in the classroom had to be known. Teaching-learning activity is one of the issues that affected students' learning and conceptual development. The actions and details of classroom atmosphere affected science learning could be explained by teacher. Therefore, researcher conducted this study to investigate the science learning problems through science teacher.

Based on PISA Thailand criteria of sampling, all nine areas were selected and each area consisted of having O-NET test scores of academic year B.E. 2556(A.D. 2013) at high, moderate and low levels. Those nine areas throughout Thailand were upper northern, lower northern, upper northeastern, lower northeastern, west, eastern, southern, central, and Bangkok of Thailand. The schools were located in rural area, city and big city areas.

1.1.1 Population and participants

The population included science teachers who taught grade eight students in public schools all over Thailand.

The participants were 36 science teachers who taught grade eight students and were willing to respond to the given question from 36 schools located in nine areas based on PISA Thailand criteria of sampling. Four science teachers were from each area. They were selected by cluster random sampling.

1.1.2 Research instrument and data collection

Data was collected by opened-question *"What problems have mostly found in your science classroom?"* Five teachers were interviewed via telephone for obtaining more details and for the reliability of the data. Those teachers were from five schools which

placed at different school achievement and located both urban and rural area of upper northeastern, lower northeastern, upper northern, southern, and Bangkok areas.

1.1.3 Data analysis

Data was analyzed by content analysis. Teachers' answers were grouped into five groups. Findings, the highest problem found in science classroom was problem related students' behavior (38.46%) and the second was students' lacking of science process skills and less awareness while doing the experiment (35.89%) while problem related students' language ability (5.13%), lacking of laboratory equipment (10.26%) and curriculum (10.26%) were revealed (seeing in Chapter 4 for more details).

Although problems related students' behavior had found the highest percentage but it had many factors affecting and needed long time to shape and change. Therefore, researcher continued to solve the problem related students' science process skills and their awareness because it is crucial in science education.

In addition, the problem related students' lacking of science process skills and were not aware while learning were hypothesized to affect to students' achievement on science literacy. According to the PISA 2015 framework that showed that, scientific literacy was assessed through three competencies; explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically (OECD. 2013: 7). However, those competencies were made in such a way that 15-year-old students could reasonably use three knowledge included content knowledge, procedural knowledge, and epistemic knowledge to apply their scientific knowledge in the context of their life situations; personal, local/national, and global level. In terms of procedural knowledge referred to the procedures and strategies used in all forms of scientific enquiry and in details has related to science process skills which were shown in Table 9.

TABLE 9 The consideration of science process skills in procedural knowledge

Details of Procedural Knowledge	Science Process Skills
The concept of variables including dependent, independent and control variables	Defining variables operationally
Concepts of measurement *e.g.*, quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables	Observing, Classifying
Ways of assessing and minimizing uncertainty such as repeating and averaging measurements	Measuring Experimenting
Mechanisms to ensure the reliability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure)	Measuring
Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use	Communicating Interpreting data
The control of variables strategy and its role in experimental design or the use of randomized controlled trials to avoid confounded findings and identify possible causal mechanisms	Inferring Identify and controlling variables
The nature of an appropriate design for a given scientific question *e.g.*, experimental, field based or pattern seeking	Experimenting Predicting Formulating hypotheses

Additionally, the three competencies required the procedural knowledge in terms of knowledge of standard forms and procedures used in scientific enquiry to obtain data/ fact for the competency of explain phenomena scientifically, in terms of common procedures used in science for the competency of evaluate and design scientific enquiry and in terms of understand the procedures that had been applied to obtain any data set for the competency of interpret data and evidence scientifically (OECD. 2013: 8-9). It could be concluded on Figure 15.

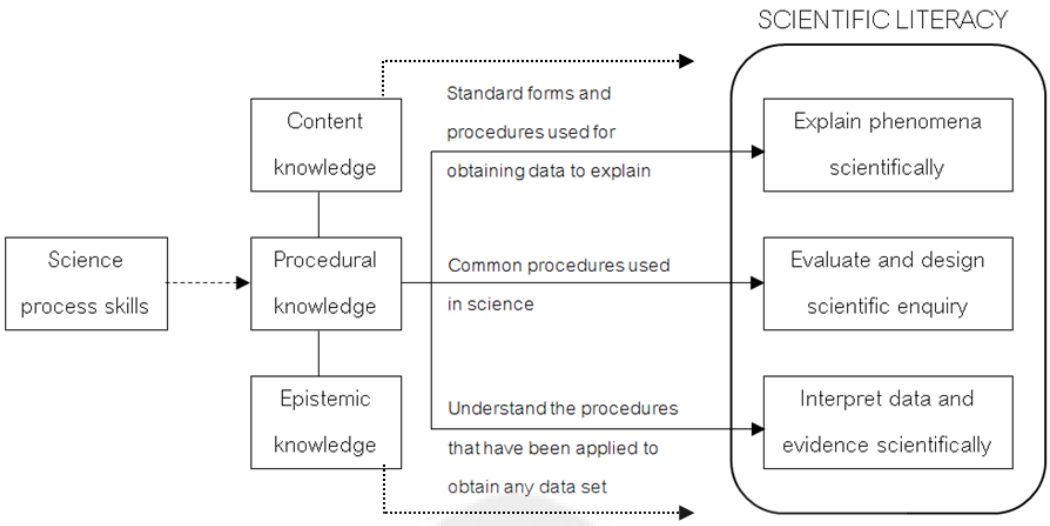

FIGURE15 The connection between science process skills and science competencies

Moreover, PISA 2006 included measurement of self-efficacy in science which referred to students' belief in their own abilities to handle tasks effectively and difficulties. It seemed to be a key impact to motivation; a strong sense of self-efficacy could affect students' willingness to take on challenging tasks and also referred to how much effort and persist students are (Bandura. 1994: 2). That measurement focuses on students' self-efficacy in science in term of applying science to daily life. Students were asked to rate the easy with which they believed they could perform eight listed scientific tasks such as (i) recognize the science question that underlies a newspaper report on a health issue (ii) explain why earthquakes occur more frequently in some areas than in others (iii) identify the science question associated with the disposal of garbage. The results showed that even Thai student' science achievement was weak (lower than OECD mean scores average) but their self-efficacy seemed high. It was 0.078 of standardized self-efficacy mean score and was stronger than OECD average mean score (OECD. 2007: 135). That means Thai student' achievement was weakly predicted their motivation by self-efficacy.

Based on the results of teachers' opinions and the report of PISA assessment, it could be demonstrated the connection of problems in Thai science classroom might effect to students' performance including Thai students on self-efficacy issues which needed to be solved, that was shown on Figure 16.

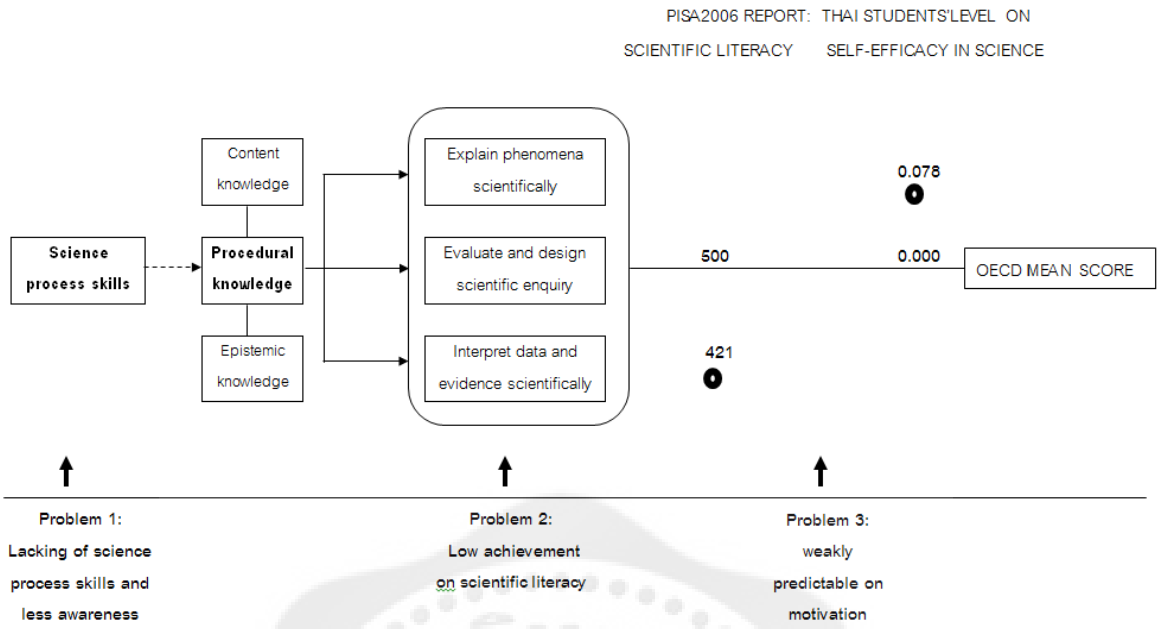

FIGURE 16 The connection of problems in Thai science classroom and students' performance in PISA assessment 2006

Consequently, the researcher aimed to find the learning model which could improve students' science process skills with awareness that what they did while learning including improved students' self-efficacy to be more consistency with students' performance. Furthermore, previous studies had shown positive correlation between science process skills and science achievement in many studies (Ong Saw Lan. 2006; Aydogdu. 2007) however it was found no have correlation in the study of R.Gokul Raj & S.Nirmala Devi (2014) It had never found the study related to the correlation between science process skills and science competencies therefore researcher aimed to study its correlation in this study. According to the data were collected from science teachers who taught eighth grade students at a very beginning of first semester, Therefore, it demonstrated that students had problems related to the lacking of science process skills since they were in seventh grade, which was the first level of lower secondary school. Thus, this study aimed to improve students' performance on science process skills, science competencies and self-efficacy of seventh grade students.

1.2 An exploration of students' level of science process skills

According to the teachers' opinions that had mentioned the students' lacking of science process skills lead this study to being aimed at developing the learning model to solve both students' awareness while learning and enhancing students' science process skills. To know clearly about students' level abilities of science process skills and lower secondary school students' trend on process skills were required in order to be the basic data to design lesson plans and learning activities especially belonged to the learning model. Consequently, the survey was conducted.

1.2.1 Population and participants

The population included lower secondary school students in Bangkok was 230,101 students which were consisted of 116,526 boys and 113,575 girls in 2017 academic year.

The participants were 426 students who were lower secondary school students in Bangkok in 2017 academic year. They were selected by using technique 5% of the Yamane formula, stratified random sampling and simple random sampling, respectively.

1.2.2 Research instrument and data collection

Data were conducted from 426 lower secondary school students which were consisted of 189 of seventh grade, 113 of eighth grade, and 124 of ninth grade students in Bangkok during August – September 2017 in first semester of 2017 academic year.

1.2.3 Data analysis

Data were analyzed by mean, standard deviation, and percentage. Previous studies have shown the level of students' science process skills abilities were categorized into three levels namely low, moderate, and high by mean score in various criteria; Tilakaratne & Ekanayake (2017) set at 36-79% as moderate level for sixth and seventh grade students, Su krno et al (2013) set at 36% - 79% as moderate level for eighth grade students Raj & Deri (2014) set at 30% - 69% as moderate level for high school students, and Seetee (2016) set at 36 – 64% as moderate level for eleventh grade school students. Researcher set at 45% and 65% to category into three levels; low, moderate, and high where upper than 65% of total score was high, lower than 35% of total score was low and mean score between 45 – 64% of total score was moderate level. It revealed that students'

level of science process skills was at moderate level (45-64%). The details of findings were shown in Chapter 4.

Stage 2: Development of learning model and research instruments

2.1 Developing the metacognitive strategy embedded in inquiry learning model

2.1.2 Developing and verifying the learning model

The metacognitive strategy embedded in inquiry learning model was infused between inquiry based learning approach and metacognitive theory in terms of the regulation of cognition in an attempt to solve the problems of students lack science process skills and less awareness while learning science which affects them. They could not identify the purpose of experiment, had no plan on working and did the procedure wrong during the experiment. These demonstrated that students needed more plans and the goal of the tasks needed to be set as well as the procedure needed to be monitored while learning science. Therefore, this learning model was developed to enhance students on science process skills through proposing the ways to make exploration and encourage them to have the goal of learning and always aware the goal while learning in order to accomplish science tasks/experiments. Based on enhancing those two purposes, students' science competencies and self-efficacy were hypothesized to be improved. Consequently, the dependent variables of this study were students' science process skills, science competencies, and self-efficacy in science. The processes of developing the metacognitive strategy embedded in inquiry learning model were as followed:

(1) Reviewed and analyzed the information related the development of science process skills and students' regulation in learning. According to fifteen previous studies related science process skills development, it had found that inquiry based learning was mostly used. In addition, the studies related metacognition learning especially using of Interactive Student Notebook (ISNs) embedded with metacognitive strategies showed positive association with understanding of concepts and impacted the students' science process skills. Schraw and et al (2006) suggested that metacognition enables individuals to monitor current knowledge and skills in science learning effectively. Additionally, the regulation of cognition could help novice students be trained by a systematic regulatory

sequence and helped them to control their performance and became more strategic and systemic (King 1991 cited in Schraw. 1998) and students got more effective for solving more complex problems (Delclos and Harrington. 1991). Consequently, inquiry learning and regulation of cognition were considered to develop the learning model to solve that addressed problems in science classroom from the teachers' opinions.

(2) Determining the goal of learning model included feature, objective, and outcomes in each phase of learning model.

(3) Developing first draft of the learning model by infusing 5E inquiry (Engagement, Exploration, Explanation, Elaboration, Evaluation) and Metacognitive theory in terms of regulation of cognition (planning, monitoring, evaluating) was the main step as was 5Es inquiry and was driven by the flexible cycle of planning-monitoring-evaluating in 3Es phase included Exploration, Explanation, and Elaboration phases. (see Figure 17)

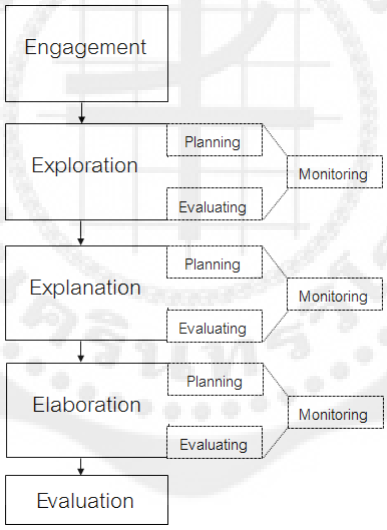

FIGURE 17 First draft of the metacognitive strategy embedded in inquiry learning model

(4) Determining the suitable content to objectives and outcomes of learning model.

(5) Writing and considering first draft of lesson plan based on the metacognitive strategy embedded in inquiry learning model in order to appraise the possible.

(6) Verifying and revising the first draft of learning model by advisors and the committees of proposal dissertation presentation. It was revised by adding the cycle of planning-monitoring-evaluating in Engagement phase. All cycles of regulation was driven with step sequence: planning-monitoring-evaluating. It became to the second draft (see Figure 18)

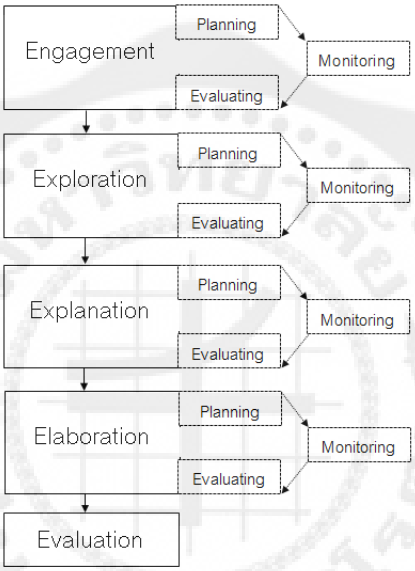

FIGURE 18 Second draft of the metacognitive strategy embedded in learning inquiry model

(7) Writing the draft of the metacognitive strategy embedded in inquiry learning model document in order to submit to the experts. The document was consisted of six parts: 1) Background 2) Principle 3) Purposes 4) Learning process 4) Objectives and Roles of student and teacher 5) Contribution.

(8) Examination of the draft of the metacognitive strategy embedded in inquiry learning model document and lesson plan by advisors and revising based on their suggestions. The details of second draft of the metacognitive strategy embedded in inquiry learning model before submitting to the experts were concluded as following:

The learning model was comprised of five main phases of 5E inquiry and was driven on four phases by cycle of regulation with step sequence: planning (P)-monitoring (M)-evaluating (E) in Engagement, Exploration, Explanation, and Elaboration phase. (see Figure 18) The description, objective, and feature of each learning process phase were shown in Table 10

TABLE 10 Features of the metacognitive strategy embedded in inquiry learning model

Phase	Feature in each phase	Source
Engagement + P-M-E	Learner is able to make a plan, monitor and evaluate while learning and perceive own capabilities both knowledge and process. Interested in science question and engages in scientifically oriented questions to formulate science question (testable question).	-Regulation of cognition -Inquiry learning -Self-efficacy; in term of social persuasion
Exploration + P-M-E	Learner is able to make a plan, monitor and evaluate while learning and perceive own capabilities both knowledge and process. Learner gives priority to evidence in responding to questions.	-Regulation of cognition -Inquiry learning -Self-efficacy; in term of social persuasion
Explanation + P-M-E	Learner is able to make a plan, monitor and evaluate while learning and perceive own capabilities both knowledge and process. Learner formulates explanations from evidence, connects explanations to scientific knowledge and communicates and justifies explanations	-Regulation of cognition -Inquiry learning -Self-efficacy; in term of social persuasion
Elaboration + P-M-E	Learner is able to make a plan, monitor and evaluate while learning and perceive own capabilities both knowledge and process. Learner engages in scientifically oriented questions to formulate science question or goal, formulates explanations from evidence and connects explanations	-Regulation of cognition -Inquiry learning -Self-efficacy; in term of social persuasion

TABLE 10 (Continued)

Phase	Feature in each phase	Source
	to scientific knowledge including communicates and justifies explanations	
Evaluation	Learner communicates and justifies explanations that lead one perceives own capabilities whole knowledge and skills they have learned by doing self-evaluation form which affect to self-efficacy in science.	-Self-efficacy; in term of mastery experience

The detail of each phase was shown as following;

Engagement P-M-E phase: Students are engaged with instructional material; media, article, news, phenomena which was related to science topic to learn. Students make self-evaluation on prior knowledge; what they know, what they have to know while doing the activities. Teacher engaged students to make the science questions (testable) and then make discussion about those science questions (testable). Students consider about the contextual related those article/news/phenomena relate to the question. Students monitor and evaluate the question they have formulated through discussion. Finally, they reach the complete science questions (testable).

Exploration P-M-E phase: students work in collaboration and make small group discussions about the plan in terms of prior knowledge, time, person, goal, and discuss in the whole class discussion before doing the experiment or science tasks. Students monitor while on process such as the failure or what have to fix and evaluate when finish the task by checklist with the plan/goal. Teacher probably prepares instructional material for instance poster, show the text via PowerPoint, or even by teacher's verbal to engage students continually regulate themselves while doing task.

Explanation P-M-E phase: students formulate explanation based on data/evidence and connect with scientific knowledge. Students recall the goal in the plan and make checklist the evidences. Students have to plan the priority of thinking in explanation and monitor what they have explained through group discussion. Finally,

students connect to science knowledge and complete explanation. Teacher is being as a facilitator-to engage students to monitor and correct students' writing explanation.

Elaboration P-M-E phase: This phase aims to have students apply all the knowledge and skills they have learned in 3Es to another circumstance/ phenomena including exploring the assigned science tasks or exploring what student's interested in. Therefore, students have to formulate science question (testable), formulate explanation of exploration based on evidence and connect with scientific knowledge. Students plan, monitor and evaluate while doing in procedure in order to communicate justification knowledge. This phase make students perceive their own capabilities in knowledge and skills. Teacher prepare the phenomena/situation and being as facilitator: to help and question in order to make student accomplish the tasks.

Evaluation phase: students are evaluated all knowledge and skills they have learned from worksheets, giving opinions, and journal entires. Students perceive their capabilities.

(9) Verifying the metacognition strategy embedded in learning inquiry model by three experts. The learning model was verified the content validity in terms of index of consistency (IOC) which was considered the consistency index between item and objective and was given the comments and suggestions. If the IOC was higher than 0.5 that means acceptance due to at least 50 percent of experts gave a perfect rating to the item the learning model would have internal consistency (Cojorn. 2011: 75).

(10) Revising the metacognitive strategy embedded in inquiry learning model based on comments and suggestions of experts.

(11) Pilot study the learning model with grade seventh students.

(12) Revising the learning activities suited to the learning model.

2.2 Developing research instruments

There were three research instruments which were collected the data in this study: Science process skills test, Science Competencies test, Self-efficacy in science. All research instruments were developed by researcher. Each research instrument was described as follows;

2.2.1 Science process skills test

It was consisted of two parts: 1) the 24 items of basic science process skills test and 2) the 16 items of integrated science process skills test. Some questions were adapted from Afif Hafez Zeidan and Majdi Rashed Jayosi (2015) and Louise E. Shive (2002). The test consists of 49 items of multiple choices with 4 options in first draft. It was a paper-and-pencil test of well-known situations and not relate to the content. The procedures of test development were as follows;

(1) Defining the definition of science process skills and were determined into the objective of each test item. The definition of basic and integrated science process skills were as follow;

1.1 Basic science process skills

1.1.1 *Observing*: is using five senses (seeing, hearing, smelling, tasting and touching) to gather information about objects and events for getting their properties or changing.

1.1.2 *Classifying:* is grouping objects or events into categories based on information collecting and according to objectives. Information can be classified at many types and levels; from very general to very specific. .

1.1.3 *Measuring*: is making information from observation clearly by comparing some attribute of a system to a standard of reference. Making information observation into numerical term and it should be given in SI units. However, measuring use both appropriate standard and non-standard measures/estimates to describe the dimensions of an object or event.

1.1.4 Using space/time relationship: is the process skills of relationships deals with the interaction of variables. Relationships can be multiple or single dimensions such as speed with distance and time representing is the example of two

dimensions or the location in space is the example of single dimension. Describe an object's position i.e. above, below, beside, etc., in relation to other objects, the motion, direction, spatial arrangement, symmetry, and shape of an object compared to another object.

1.1.5 Using number: is represented observation information in terms of numbers. Identify quantitative relationship in nature. Using number can be reduced the verbal meaning and allowed to apply logic of mathematics to describe and understand nature.

1.1.6 Communicating: is the process of presenting information of objects or events to people by taken in many forms: verbal, written, non-verbal, or symbolic. This process moreover refers to a group of skills which using to present in form of reporting data. It mostly has display in terms of tables, charts and graphs.

1.1.7 Predicting: is a process which forecasts future outcome based on information and evidence existed. Use of evidence to formulate the sequence of a forthcoming process of action or outcome. Forecast events based on observations/previous experiences/ certain patterns of reliable data.

1.1.4 *Inferring:* is explanation or interpretation of an observation which be generated from "educated guess" about events or objects based on gathering data and information. Suggest explanations for events based on observations, analyses the cause and effect of decision, organize the observed data in a logical sequence leading to possible solutions.

1.2 Integrated science process skills

1.2.1 *Defining operationally:* is to define the attributes of variables to a concept by specific and be able to state method to measure those variables.

1.2.2 Formulating hypotheses: is the expected outcome of an experiment. Identify questions or statements which can and cannot be tested design statements.

1.2.3 *Interpreting data*: is organizing and analyzing data to draw conclusions from it. Identify the relationship between the variables, from a given graph /

table of data (relating to an investigation), draw reasonable conclusions from the data by determining apparent patterns or relationships in it.

1.2.4 *Identify and controlling variables:* is to identify variables that can affect an experimental outcome keeping most constant while manipulating only the independent variable. Identify the variables that may affect the dependent variable as stated in a problem.

1.2.5 *Experimenting:* is to be able to conduct an experiment, making appropriate questions stating a hypothesis, identify and controlling variables, operationally defining those variables designing a "fair" experiment, identify what is to be measured or compared , select a suitable design and tools for an investigation, and interpreting the results of the experiment..

(2) Developing forty-nine items; thirty items of basic science process skills test and the nineteen items of integrated science process skills test in first draft.

(3) Examination of the draft of science process skills test by advisors and revising based on their suggestions.

(4) Verifying the validity in terms of index of consistency (IOC) by five experts; three experts were in field of science education and two experts were in field of educational measurement and evaluation. There were forty-eight items having IOC between 0.67 – 1.00 and one item had to be revised according experts' suggestions as the IOC was below 0.50.

(5) The test was tried out by one hundred of seventh grade students from schools in Bangkok during January 2017.

(6) Calculating the reliability (KR-20) of the test, an average item difficulty (p) and the discrimination index (r). Finally, there were forty items in the test which was consisted of twenty-four items of basic science process skills and the sixteen items of integrated science process skills. Technique 27% of Chung The Fan was used for calculating the discrimination index (r) was between 0.20 – 0.80 and the difficulty index (p) was between 0.20 – 0.80. The reliability (KR20) of the test was 0.83 which was high reliability due to the generally acceptable value was up 0.70 (Worrakam. 2011:297 cited in Seetee

2016: 68). The details about science process skills development were shown in APPENDIX B.

(7) Using the test in evaluating stage.

2.2.2 Science competencies test

According to the definition of science competencies in this study was belonged to the framework of science literacy of PISA 2015 which consists of three competencies: 1) explain phenomena scientifically 2) evaluate and design scientific inquiry 3) interpret data and evidence scientifically. It became the template to construct the test in terms of the proportion weight of each competency and test type. Therefore, the test was consisted of twenty-two items of three competencies; 1) there were 40% or 9 items of explain phenomena scientifically (PISA 40-50%) 2) there were 22% or 5 items of evaluate and design scientific enquiry (PISA 20-30%) 3) there were 36% or 8 items of interpret data and evidence scientifically (PISA 30-40%). However, the test comprises thirty items in the first draft which was a mixture of three test format included multiple choice, complex choice (true false), and writing (open-ended response). The test content related to atmosphere and climate which focus on the situations relating to personal, community (local/national), and life across the world (global). The procedures of test development were as follows;

(1) Defining the definition of science competencies from PISA 2015 framework were as follows (OECD. 2013: 14 - 17):

Competence 1: Explain phenomena scientifically

Referred to recognize, offer and evaluate explanations for a range of natural and technological phenomena demonstrating the ability to: -Recall and apply appropriate scientific knowledge; Identify, use and generate explanatory models and representations; Make and justify appropriate predictions; Offer explanatory hypotheses; Explain the potential implications of scientific knowledge for society.

Competence 2: Evaluate and design scientific enquiry

Referred to describe and appraise scientific investigations and propose ways of addressing questions scientifically demonstrating the ability to: -Identify the question explored in a given scientific study; Distinguish questions that are possible to investigate scientifically; Propose

a way of exploring a given question scientifically; Evaluate ways of exploring a given question scientifically; Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations.

Competence 3: Interpret data and evidence scientifically

Referred to analyze and evaluate scientific data, claims and arguments in a variety of representations and draw appropriate conclusions demonstrating the ability to: -Transform data from one representation to another; Analyze and interpret data and draw appropriate conclusions; Identify the assumptions, evidence and reasoning in science-related texts; Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations; Evaluate scientific arguments and evidence from different sources (*e.g.* newspaper, internet, journals)

(2) Studying the test format of science literacy of PISA

(3) Considering and determining the science curriculum standard and the definition of competency in order to integrate with suitable situations including weight percentage of competencies.

(4) Constructing the test based on real data/information related atmosphere, weather, and climate in the world nowadays.

(5) Examination of the draft of science competencies test by advisors and revising based on their suggestions.

(6) Verifying the validity in terms of index of consistency (IOC) by three experts; three experts; two experts were in field of science education and one expert who has been working as academician of PISA Thailand, Institute for the Promotion of Teaching Science and Technology. There were twenty nine items having IOC between 0.67 – 1.00 and one item had to be revised according experts' suggestions as the IOC was below 0.50. See APPENDIX B.

(7) The test was tried out by one hundred-twenty of seventh grade students from schools in Bangkok during January 2017.

(8) Scoring test was different based on test format. However, it all finally needed to be converted to a 0 to 1 scoring. The details about scoring each format were as follows:

8.1 Multiple choices (MC)

This part consists of 3 items of multiple choices with 4 options. The test was scored right/wrong with the code “1” for right and “0” for wrong.

8.2 Complex choice (true false)

This part consisted of 14 items of complex choice with three alternative questions of true-false of one item. Students had to read the situations which some concepts related scientifically were selected as three questions. Students had to identify true or false on three given question (three answers) in each item. The test was scored right/wrong with the code “1” for right and “0” for wrong. As a result, the full score of each item was 3 scores and students probably got completely wrong, partial, half, or full score for fully correct answer (i.e. get 0, 1, 2, or 3) depended on how well students answered. The scoring of each item on actual test was 0 – 3 integer scale however partial credit for items were calculated in order to convert score to be 0 – 1 scale. Therefore, Brown (2000) suggested that a 0 – 3 integer scale (i.e., a 0, 1, 2, and 3 scale) can be converted as follows:

0.00 for students who answer completely wrong due to (0/3 = 0.00)

0.33 for students who answer one-third correctly due to (1/3 = 0.33)

0.67 for students who answer two-third correctly due to (2/3 = 0.67)

1.00 for students who answer completely correctly due to (3/3 = 1.00)

8.3 Writing (open-ended response)

This part consisted of 13 items of open-ended response. Students had to read the situations related scientifically phenomena and responded to the question by writing the answer. The scoring of each item on actual test was 0 – 3 integers scale. Students could be scored: “0” for completely wrong, “1” for one-third correctly, “2” for two-third correctly, and “3” for completely correctly. The answer criteria were scoped

clearly for each item. Two experts in field of science education participated as the investigator triangulation in order to make more accurate scoring. Finally, a 0 – 3 integer scale (i.e., a 0, 1, 2, and 3 scale) were converted to be a 0 to 1 scoring by partial credit for items same as complex choice (true false) test format. An example of scoring criteria of writing test was shown in APPENDIX D

(9) Calculating the reliability (KR-20) of the test, an average item difficulty (p) and the discrimination index (r). Technique 27% of Chung The Fan was used for calculating the discrimination index was between (r) 0.20 – 0.91 and the difficulty index (p) was between 0.21 – 0.89. The reliability (KR20) of the test was based on test format: 0.42 for multiple choice, 0.53 for complex choice (true false), and 0.53 for writing (open-ended response), respectively. Finally, there were twenty-two items in the test which was consisted of nine items of explain phenomena scientifically, five items of evaluate and design scientific enquiry, and eight items of interpret data and evidence scientifically. The details about science competencies test development were shown in APPENDIX B.

(10) Using the test in evaluating stage.

2.2.3 Self-efficacy in science test

Referred to four main sources influence to level of self-efficacy included mastery experience, vicarious experience, social persuasion, and physiological state. mastery experience was the most influential to form perceived efficacy (Bandura. 1994; Pajares. 2005: 296; Britner; & Pajares. 2006: 486). In this study, positive feedback from researcher and students' monitoring through whole classroom discussion (social persuasion) were used and especially was emphasized on developing self-efficacy level by mastery experience which students would perceive their capabilities based on their success on given tasks by self-evaluation form at evaluation phase of this learning model. Therefore, self-efficacy in science test was developed by researcher was that asking related the specific task that students had experienced in the classroom. Students were presented with items portraying different levels of task demands and they rated the strength of their belief in their capabilities to execute the tasks which were evaluated in terms of their level of students' confidence in four aspects: 1) explanation in science lesson they have learned

(scientifically), 2) planning and designing experiment and working in science, 3) applying science in daily life, and 4) presenting and communicating science lesson. There were forty-one items created in first draft. Likert scale with five point scale (strongly disagree, disagree, neither, agree, strongly agree) was used to allow the students to express their belief. The procedures of test development were as follows;

(1) Defining the definition of self-efficacy in science into four aspects as follows;

Aspect 1: explanations in science lesson they have learned (scientifically): Referred to students' belief relates their level of capabilities in scientifically explanation by using science principles they have learnt to explain the phenomena through belief in their capabilities to connect content or resources to explain scientifically or those phenomena. There were eight items to measure this aspect.

Aspect 2: planning and designing experiment and working in science: Referred to students' belief relates their level of capabilities in using science equipment and science process skills to propose or design the ways for exploration include belief on their effort to do science tasks successfully. There were eleven items to measure this aspect..

Aspect 3: applying science in daily life: Referred to students' belief relates their level of capabilities in applying science knowledge in daily life, identify evidences/reasons scientifically include evaluate argument issues and evidences from any resources in daily life (news, article, social media etc.). There were sixteen items to measure this aspect.

Aspect 4: presenting and communicating science lesson

Referred to students' belief relates their level of capabilities in analysis and interpret scientifically data in order to communicate in terms of verbal, writing, discussion and explanation to others. There were seven items to measure this aspect.

Due to the items portraying consisted of positive and negative statement thus Likert scale with five point scale (strongly disagree, disagree, neither, agree, and strongly agree) was converted code as follow:

TABLE 11 Point values for positive and negative items

	Positive items	Negative items
Strongly disagree	1	5
Disagree	2	4
Neither	3	3
Agree	4	2
Strongly agree	5	1

(1) Studying the test format of self-efficacy and constructing the test. There were forty-one items created in first draft. Researcher had adjusted this test based on the study of Lin & Tsai (2012).

(2) Examination of the draft of self-efficacy in science test by advisors and revising based on their suggestions.

(3) Verifying the validity in terms of index of consistency (IOC) by three experts; two experts were in field of science education and one expert who has been working as academician of PISA Thailand, Institute for the Promotion of Teaching Science and Technology. The IOC of forty-one items were between 0.67 – 1.00. Revising some items based on experts' comments and suggestions.

(5) Pilot with one hundred of eighth grade students from a school in Bangkok during September 2017

(6) Calculating reliability (Cronbach's alpha) of the test was 0.91. The details about self-efficacy in science test development are shown in APPENDIX B.

(7) Using the test in evaluation stage.

Finally, the validity in terms of index of consistency (IOC), difficulty index (p), discrimination index (r) and the reliability (KR20 and Cronbach's alpha) of all research instruments were summarized in Table 12.

TABLE 12 The validity and reliability of each research instrument

Test	IOC	Students in Try out	Difficulty index (p)	Discrimination index (r)	Reliability
Science process skills	0.40* – 1.00	110	0.20 – 0.80	> 0.20	0.83
Science competencies					
-Multiple choice			0.20 – 0.89	> 0.20	0.42
-Complex choice	0.67 – 1.00	120	0.20 – 0.80	> 0.20	0.53
-Writing			0.20 – 0.80	> 0.20	0.53
Self-efficacy in science	0.67 – 1.00	100	-	-	0.91

* One item then is already revised based on the experts

2.3 Designing and developing the lesson plans and instruction materials

2.3.1 Developing the lesson plans

This study had selected the concept of “Atmosphere and Climate” to be the main concept for testing the hypotheses. Based on an exploration of lower secondary school students’ level of science process skills were not high and in order to prepare for the PISA assessment which measure student 15-year-old thus this study was more focusing on integrated science process skills especially experimenting skill and gave students more chance to design own experiment based on their experience and everyday language while planning. The procedures were as follows:

(1) Analyzing contents, main concepts and review documents related to atmosphere and weather such as article, journal, news, experiment and misconception about atmosphere and weather etc.

(2) Determining learning objectives based on IPST curriculum (see Table 14) and outcome of the metacognitive strategy embedded in inquiry learning model. However, based on the purpose of this study, the sequences of contents needed to be arranged in order to be more coherent.

TABLE 13 The contents of atmosphere and weather

Contents	Keywords	Time (hour)
Layers of atmosphere	Troposphere, Stratosphere, Mesosphere Thermosphere, Atmosphere, Air	1.5
Effect of solar radiation to atmosphere	Reflection and absorption Solar Radiation	1.5
Air Temperature	Air Temperature, Thermometer	1.5
Air Pressure	Air Pressure, Barometer	1.5
Wind	Wind, Wind Vane	1.5
Humidity	Humidity, Relative humidity, Cyclometer	2.5
Cloud and Rain	Cloud, Cumulus, Status, Cyrus, Rain,	2.0
Thunderstorm	Thunderstorm, Lighting, Thunder, Gust	1.5
Tropical storm	Tropical storm, Depression, Tropical cyclone, Cyclone, Typhoon, Hurricane	1.0
Monsoon	Monsoon	1.0
Weather forecast	Weather forecast, Weather maps, Weather station	1.0
El Nino and La Nina	El Nino and La Nina	1.0
Earth's temperature change	Greenhouse effect, Greenhouse gas	1.0
Air pollution	Air pollution, acid rain	1.5
	Total	20

Source: The Institute for the Promotion of Teaching Science and Technology (IPST). 2010. Teacher's Guidebook: Science 2 for seventh grade students. Bangkok.

(3) Considering and creating the overview schedule in terms of time, contents, concept, learning objectives, activities to enhance science competencies, science process skills, self-efficacy, in each lesson plan (L.P.).

TABLE 14 The determining of objectives and overview of using learning model

L.P	Concept	Learning objective	Learning activity	Science competencies	Science process skills	Self-efficacy
1	Atmosphere	-characterize the layers of the atmosphere and the benefit of atmosphere	-Watching VDOs and discussion	Interpret	-COM	Mastery experience and positive feedback
2	The effect of sun rays to atmosphere and air temperature	-Do the experiment, discuss and explain the effect of sun' s ray to temperature on surface -Interpret the graph of temperature in one day and analyst factors affecting temperature	-Lab1 -Discussion	Design Interpret Explain	-OBS -MEA -NUM -SPC -INF -HYP -DEF -VAR -EXP	Mastery experience and positive feedback
3	The effect of temperature to air density and air pressure	-Do the experiments and explain the relationship between temperature and	-Lab 2 -Discussion -Lab 3	Design Interpret Explain	-OBS -MEA -SPC -INF -HYP -DEF	Mastery experience and positive feedback

TABLE 14 The determining of objectives and overview of using learning model (continued)

L.P	Concept	Learning objective	Learning activity	Science competencies	Science process skills	Self-efficacy
		air pressure including air density -Explain the relationship between amount of air molecule and air pressure -Describe how barometer			-VAR -EXP	
4	Wind	-Do the experiment and explain the relationship between air pressure and wind -Identify the pros and cons of wind	-Lab 4 -Discussion	Design Interpret Explain	-OBS -INF -HYP -DEF -VAR -EXP	Mastery experience and positive feedback
5	Humidity	-Do the experiment and find the relative humidity -Explain the relationship between temperature and humidity	-Lab 5 -Watching VDOs and discussion	Design Interpret Explain	-MEA -PRD -NUM -EXP -INF	Mastery experience and positive feedback
6	Cloud and precipitation	-Investigate and explain cloud formation, types of cloud, precipitation	-Searching -Discussion -Watching Drama	Explain	-CLS -COM	Mastery experience

TABLE 14 (continued)

L.P.	Concept	Learning objective	Learning activity	Science competencies	Science process skills	Self-efficacy
7	Thunderstorm and tropical storm	-Searching and identify the difference between thunder storm and tropical cyclone -Characterize tropical cyclone -Identify the destroy and explain how to protect -Interpret graph and choose appropriate way to present data	-Searching -Game -Discussion	Interpret Explain	-PRD -COM -INT -NUM -SPC -INF	Mastery experience and positive feedback
8	Weather forecast	-Explain and interpret the symbols on weather forecast map -Choose an appropriate way present the data	-Watching news -Discussion -Criticize effective method to present	Interpret Explain	-COM -CLS	Mastery experience and positive feedback
9	Climate change El nino, La nina, greenhouse effect, global warming and air-pollution	-Searching, explain and analyst the causes and effect of global warming'	-Role play -Discussion based on social issues	Interpret Explain	-COM -INT	Mastery experience and positive feedback

TABLE 14 (continued)

L.P.	Concept	Learning objective	Learning activity	Science competencies	Science process skills	Self-efficacy
9	Climate change, El nino, La nina, greenhouse effect, global warming and air-pollution	-Analyst and discuss about cause and effect of ozone hole, acid rain and air pollution -Describe the effect of El nino and La nina to weather				

**OBS: observing, CLS: Classifying, SPC: Using space/ time, NUM: Using number, COM: Communicating, PRD: Predicting, INF: Inferring data, DEF: Defining operationally, HYP: Formulating hypotheses, INT: Interpreting data, VAR: Identifying and controlling variables, EXP: Experimenting

(4) Creating nine lesson plans. According to the results of students' science process skills survey lead the lesson plans mostly were focused on hypotheses formulating and experimenting skills than other skills when the learning activities had to do experiments. An interactive student notebook (ISNs) was the important tool to reflect while students were planning and doing the experiment.

- *The interactive student notebook (ISNs)*

The ISNs was created to have compatibility with sequence cycle of regulation in which showed the plan in the left side and the outcomes in the right side. Furthermore, the monitoring step can do from checking list between left and right sides and evaluating step was fulfilled in the right side of outcomes. The ISNs was used in terms of experiment activities in 3Es; engagement, exploration, and explanation phase of this learning model.

Left side: page 1	Right side: page 1
Planning	-Testable question (E3)
-Testable question (E1)	-Purpose (E3)
-Experiment (casual verbal) (E2)	-Hypothesis (E3)
-Diagram of experiment (E2)	-Variables/ Define variable (E3)
	-Material/equipment (E3)
Left side: page 2	**Right side: page 2**
-Recall and plan for explanation (E4)	-Results
-Connection	-Checklist what doing/error
-Reflection	-Conclusion (E5)
-Extension	-Scientific Explanation

FIGURE 19 The interactive science notebook embedded in regulation of cognition

- *Designing experiment procedures based on students' experience*

According to previous study suggested that students do the experiment by following the procedure in lab sheet lead students do not aware which variables through forming hypothesis. Consequently, students were not concern of the importance of identifying the variables and its implementation when they make the conclusion to experiment. Thus, teacher should ask students to identify the variables involved before doing experiment and should give students exploration questioning (Rauf; et al,. 2013: 47 - 57). As a result, this learning activities related the experiment was designed based on students' experience proposing the solution without the procedure in lab worksheet as the suggestions of Berry et al (1999) stated that following the cookbook style affects students carry out the experiment unthinkingly. Students completed the plan and

interpret all procedures and know what and why doing those steps before do the experiment on the ISNs. The preparation and conducting steps to enable students own doing experiment was shown as following:

4.1) Teacher studies and identifies the main concept and determines the purpose of experiment.

4.2) Teacher seek the example phenomena/ activities in daily life related to main concept of science learning including using the experiments were in the textbook. However, those experiments should be adjusted to make students feel more familiar. Not allow students saw textbook and any experiment procedure document. Teacher finally chose the best example/instruction material.

4.3) Teacher engaged students with the phenomena that mostly students experienced with. Encouraged and asked what students wanted to know. Students concluded the main question related those phenomena that they wanted to explore. Teacher asked what do you guess the factor to make it happen (reach -- > testable question) (E1)

4.4) Students felt free, informal atmosphere, no science technical term words were appeared. Students proposed and discussed about making solution based on their experiences. (E2). Referred to suggestions from UNESCO (2009) that students should be using the language in which they felt most comfortable, especially when meeting new ideas. They should be developing understanding first and technical vocabulary second.

4.5) Teacher listened to any ideas from students, questioning and shaping students' discussion in order to practice process skills; formulating hypotheses, identify and controlling variables, defining operationally, interpreting data, and experimenting through their plan. The casual questions to make students reach those process skills (transfer E2 to E3) were as following;

- *What do you guess the factor to make it happen? (Hypothesize)*
- *How to prove it? (Experimenting)*

  -what you know / you guess then you set it? (Determine =Independent)

  -what you do not know then you want to see? (Result=Dependent)

  -how to eliminate the bias? (Do the same=Control)

- *What is the needed evidence to confirm your guess? (Interpreting data)*
  -how to collect the evidence? (Experimenting)
  -how to know is it the right evidence? (Defining operationally)
  -what is indicator tool to collect the evidence? (Experimenting)
  -can we measure in number? (Experimenting)

4.6) Based on students' discussion, teacher gave the alternative indicator tools or materials students had proposed connects to science equipment in the laboratory.

4.7) Students drew the procedure of experiment in the left side of ISNs.

4.8) Based on discussion students wrote the plan on left side and connected to the outcomes in the right side of ISNs.

4.9) Students did the experiment and recall/checklist to the plan while doing. Data is written in the right of ISNs in terms of quantitative and qualitative data. Drawing picture was required in abstract content in order to check students' misconception such as the amount of air molecule in the same balloon when were in the hot water and water.

4.10) Students made inferring from data and made a plan for making conclusion and explanation in the left side of ISNs. The students were recalled by these questions; (E4)

- *What is the goal or testable question?*
- *What is the needed evidence to confirm?*
- *What are the results?*
- *What is interpreting of each result?*
- *Why does it happen?*
- *How?*

4.11) Students discussed about the results of experiment. Teacher could make questioning, recall prior knowledge, giving new concept relate experiment in the discussion.

4.12) Students drew conclusion and explained the phenomena in the right side of ISNs (E5) by using the recall question in a plan and monitor the explanation via checklist a plan and classroom discussion.

4.13) Students revised the complete explanation after discussion.

4.14) Students probably gave suggestions or failure they had encountered including pose another question related experiment that they were curious to make more exploration.

(5) Examination of the draft of lesson plan by advisors and revising based on their suggestions.

(6) Verifying the validity and improving the nine lesson plans by three experts: two experts in the field of science education and one in field of education.

(7) Pilot study in order to find out the suitable time and learning cycle model including other factors and then improved to become suitability.

(8) Conducting in evaluating stage.

2.4 Conducting a pilot study

This stage aimed to study the suitable of time and learning cycle model moving including other factors and then improved to become suitability.

It was conducted during November – December 2017 at a School in Bangkok. All processes of teaching were conducted by researcher. Two classrooms of 1/8 (42 students) and 1/9 (28 students) with total 70 students; one class was high-moderate achievers and emphasizing on science (English program) and one class was moderate-low achiever emphasizing on musical program in order to collect the data when researcher would use the learning model in different achievers. There were five table groups in the laboratory leaded the students were grouped 5-8 students a group. The procedures were as follows:

(1) Asking for permission to school and meeting with science teacher to explain the information of pilot study processes, period time, instructional materials, including knowing about students' background.

(2) Asking for doing pre-test of science process skills, science competencies, and self-efficacy in science

(3) Conducting a pilot study. Researcher teaches students based on phases of the metacognitive strategy embedded in learning inquiry model. Observing students' behavior, prior knowledge, responding to the activities, classroom atmosphere, other factors affecting. However, the first draft was planned for whole learning unit but it was only five lesson plans to be used as the school had many activities and events which affected to the learning time in that time. Therefore, the class was canceled. To finish the learning unit and complete for midterm examination, lecture was used for teaching in last four lesson plans instead. All observation data were written on research's journal in order to improve activities suiting to the learning model through fulfilling the features of learning model clearly.

(4) Analyzing data and revising learning activities.

Refer to IPST curriculum had set the timing for weather content as twenty hours but it needed to be arranged in the real situation. Therefore, the summary of using all lesson plans was shown in table 15.

TABLE 15 Timing of pilot study and the arrangement

Lesson plan	Plan Pilot (hr)	Pilot (hr)	Evaluating stage (hr)
Pre-Test	3.0	3.0	3.0
1. Atmosphere	1.5	3.0	3.0
2. The effect of sun rays to atmosphere and air temperature	1.5	2.0	2.0
3. The effect of temperature to air density and air pressure	3.0	3.0	3.0
4. Wind	1.5	2.0	2.0
5. Humidity	2.5	2.0	2.0
6. Cloud and precipitation	2.0	-	1.5

TABLE 15 (continued)

Lesson plan	Plan Pilot (hr)	Pilot (hr)	Evaluating stage (hr)
7. Thunderstorm and tropical storm	2.5	-	1.5
8. Weather forecast	1.0	-	1.0
9. Climate change, El nino, La nina, greenhouse effect, global warming and air-pollution	3.5	-	2.0
Post-Test	3.0	-	3.0
Total	26.0	15	24.0

However, from a pilot study gives many aspects that needed to be adjusted learning activities, those were as follows:

1) Classroom management

Due to many members in one group and that was the first time to teach students in new two classes, it was found to be difficult in managing while doing learning activities, for example a loud classroom, walking around class when learning, less answer/giving opinion, and problems while interacting between researcher and students at week 1-2. Therefore, researcher gave students a sign with their name on it to hold to their neck while they were learning science for students in M. 1/8 and they felt very excited to have it. Moreover, identifying student's name on the group picture to remember them was used for M. 1/9. As a result, students were exciting and wondering that researcher could remember all of them and they were more interested in the class; joining learning activities, more interact, have more answering/questioning or giving opinions through the researcher was calling their name when they were less attention. In other hand, classroom management had more effective. Thus, a technique of identifying student's name on the group picture was brought to use at the evaluating learning model phase.

2) Students' prior knowledge

By questioning, students could not respond to those questions directly; it was needed to give them other basic questions step by step to get the main answer. In the engage phase, students gave various questions and not pinpoint questions liked the

expected questions that were in the lesson plan. Therefore, the researcher had to reconsider and adjusted the context of engage phase. Students mostly giving alternative concepts those needed to edit. That affects timing was longer than the draft plan. To interpret and plotting graph needed time for more than one hour to make understanding however students were interested in this activities. Moreover, findings students did not like to write what they had planned or discussed and some of them had weak in their writing skill as they were slow and were fraught with misspellings. They were not making complete sentences when writing explanation or in the scientifically explanation part they wrote in a meandering fashion even when they already made the lists. Consequently, the researcher had to engage them to write, had to adjust the ISNs notebook, and added the example main context which needed to be appeared in the explanation paragraph.

3) Material instructional

The wind formation experiment had to improve in order to make students clearly understand the concept. Due to the previous tested experiment it had worked but it did not work while students were doing it in the class; the paper did not move, and the wind was not strong enough to make the tiny paper move. The Researcher used the tiny cotton fiber instead of paper in the evaluating learning model phase. The ISNs notebook had to adjust to less writing part, and added the example main context which needed to be appeared in the explanation paragraph. Moreover, by observation students expressed more interested in pictures than drawings.

4) Learning activities

Finding, misconception issues needed to be checked in monitoring step. According to students who were not confident to answer or discuss while they were planning to do the experiment and explanation leaded researcher engaged students in each group for listening their ideas and enabled to know in details what misconception students had for instance, students understood that the balloon gets bigger when put it in the hot water because of air molecule in the balloon was expanded, some of them said this was because hot water makes an air molecule go from one to many molecules and the balloon became bigger then. Even the researcher gave students questions to consider their understanding as it was hardly changing their previous belief. Furthermore, students

thought heat push the air molecules going up without moving on its own. They also thought that at the earth's surface has less air molecule than at the high altitude due to there have high temperature at the surface which affected to air movement and the amount of air molecule. In other hand, students were confused between temperature and gravity factors affecting the amount of air molecules. The significant of small group discussion was that giving more details, even if it would take up a large amount of time. Consequently, researcher had to be careful in term of the words students explain; should be asked what they mean. Researcher included checking misconception in the monitoring of explain phase and adjusted the results table of those experiments were shown students' idea about amount of air molecule and air movement in different temperature in the ISNs notebook.

5) Timing

According to the mostly encounter based pilot study, it was affective for a much longer time than was originally planned. Thus, the first draft lesson plans needed to control the time by adjusting the ISNs, checking students' understanding by answering or observing instead of checking in the worksheet in some parts, some parts had to assign the students as homework, combined some activities, less discussing in group but discussing in whole class instead, presenting at the group instead of in front of the classroom due to the students were shy and took more time to start.

Stage 3: Evaluation the effectiveness of the learning model

This stage aimed to evaluate the effectiveness of learning model affected to students' outcome. Data were collected by science process skills test, science competencies test, and self-efficacy in science test.

4.1 Research methodology

It was pre-experiment and one group pretest-posttest design was used in this study which could be used without making sampling or without control group (Bell. 2010: online cited in Thiangchanthathip. 2016: 88).

Group	O_1---------- X ----------O_2

FIGURE 20 One group pretest-posttest design

Where; -X represents the treatment using the Metacognition strategy embedded in learning inquiry model.

-O_1 represents pre-test

-O_2 represents post-test

4.2 Population and participants

The population included seventh grade students in Bangkok. The participants consisted of thirty-three of seventh grade students from a school in Bangkok. Purposive sampling was used; they were students in public school, mixed achievers, had problems in science classroom same as the results in stage 1.

Additionally, this study was verified the processes and allowed to conduct the research from the Strategic Wisdom and Research Institute, Srinakharinwirot University which was approved in the certificate of approval referring to certificate number SWUEC/E-258/2560.

4.3 Data Collection

After all research instruments were verified and revised by the experts, all research instruments were conducted in order to evaluate the effectiveness of learning model. The procedures were as follows:

(1) Meeting with students and gave them the overview; purpose and procedures of the evaluating stage of the learning mode, the learning activities schedule, record student data (such as students' name) including asking students' parents for the permission.

(2) Students did the pre-test includes 1) one hour of doing science process skills test 2) twenty-five minutes of doing self-efficacy in science test 3) one and half hour of doing science competencies test. The students' score on science process skills and midterm test score were the data to group students into 4-5 students each group by mixed abilities.

(3) Students learned science in atmosphere and weather contents based on the using of the metacognitive strategy embedded in inquiry learning model with nine lesson plans. The details about students and teacher roles of this learning model were showed in Chapter 4. Observing, checking the ISNs notebook, students' journal after finish activities in some lesson plans, and pictures during conducting the learning model were collected. Informal interview was used in order to collect students' opinion to the learning model in terms of their satisfied and the appropriateness and so on. There were seven students who volunteer to give the information via informal interview.

(4) Students do the post-test included science process skills test, self-efficacy in science test, science competencies test.

(5) Analyzing the data.

4.4 Data analysis

The statistics were used in this study consisted of two parts namely (1) basic statistic for assessing research instruments (Validity: discrimination index, difficulty index, and Reliability) and (2) the statistic for assessing research hypotheses (Mean, T-test dependent, Pearson's' correlation, Spearman's rho). Each description was described as follows:

(1) Basic statistics for research instruments

1.1 Validity

The content validity: the index of consistency (IOC) was used for examining the validity of science process skills test, science competencies test and self-efficacy in science. The three levels of rating scales were weighted by the experts. The criteria were shown as follows;

Consistent is weighted as +1

Unsure is weighted as 0

Inconsistent is weighted as -1

The formula for calculating the IOC is

$$IOC = \frac{\Sigma R}{N}$$

Where; IOC - the index of consistency

ΣR - summation of experts' opinion marks

N - a number of experts

1.2 Reliability

Science process skills test and science competencies test were examined the reliability by Kuder–Richardson (KR-20). The Cronbach's alpha coefficient was calculated on the reliability of self-efficacy in science test.

1.3 Discrimination index (r)

The test was calculated the discrimination indexes on items were science process skills test and science competencies test.

The formula for calculating the Discrimination Index (r) is

$$r = \frac{S_U - S_L}{N(X_{max} - X_{min})}$$

Where; r - discrimination index

S_U - the score summation in the upper group of each item

S_L - the score summation in the lower group of each item

N - the total number of student in the upper group and the lower group

X_{max}- the students' highest score of each item

X_{min}- the students' lowest score of each item

1.4 Difficulty index (p)

The test was calculated the difficulty indexes on items were science process skills test and science competencies test.

The formula for calculating the Difficulty Index (p) is

$$p = \frac{R}{N}$$

Where; p - difficulty index

R - the number of students who answered the item correctly

N - the total number of students who administered the item

(2) The statistics for addressing research hypotheses

According to the hypotheses of this study were: (1) Students' posttest score of science process skills was significantly higher than pretest score at .05 level (2) Students' posttest score of science competencies were significantly higher than pretest score at .05 level (3) Students' posttest score of self-efficacy in science were significantly higher than pretest score at .05 level (4)It had correlation between students' science process skills and science competencies (5) It had correlation between students' science competencies and their self-efficacy in science. Each hypothesis was analyzed by these statistics as follows:

2.1 T-test dependent -was used for testing the hypotheses:

2.1.1 Students' posttest score of science process skills was significantly higher than pretest score at .05 level.

2.1.2 Students' posttest score of science competencies were significantly higher than pretest score at .05 level.

2.1.3 Students' posttest score of self-efficacy in science were significantly higher than pretest score at .05 level.

2.2 Pearson's correlation -was used for testing the hypothesis:

2.2.1 Students' science process skills had correlated with science competencies.

The formula for calculating the Pearson Product Moment Correlation Coefficient (r_{xy}) is the sample is denoted by "r" and is by design constrained as follows

$$-1 \leq r \leq 1$$

Positive values denote positive linear correlation; Negative values denote negative correlation; A value of 0 denotes no linear correlation; The closer the value is to 1 or -1, the stronger the linear correlation.

The absolute value of "r" is defined as follows:

0.00 - 0.19	"very weak"
0.20 - 0.39	"weak"
0.40 - 0.59	"moderate"
0.60 - 0.79	"strong"
0.80 – 1.0	"very strong"

2.3 Spearman's rho -was used for testing the hypotheses:

2.3.1 Students' science competencies had correlated with self-efficacy in science.

CHAPTER 4
FINDINGS

This chapter presents the findings from *section 1*: The basic data; an exploration of problems in the science classrooms and an exploration of secondary school students' level of science process skills in Bangkok, *section 2:* the learning model development, and *section 3:* the learning model evaluation.

Section 1: Preparation stage; the basic data

The basic data were collected from teachers to understand the problems related to science classrooms and students' were surveyed on their science process skills to know what their levels of process skills were. All findings were revealed as following;

1.1 Results of an exploration of problems based on teachers' perception in the science classrooms in Thailand

Thirty-six science teachers from thirty-six schools responded to an open-ended question; asking about the problems they had mostly found in science classroom. Data were analyzed by content analysis. The percentage of problems findings and examples of quotation were showed in Table 16;

TABLE 16 The results and example quotations of an exploration of problems based on teachers' perception in the science classrooms

Themes	The example of quotations referred in each theme	Findings (%)
(i) Lacking Science process skills	➢ Wrong procedure on the experiment, ➢ Cannot use equipment appropriately. ➢ Lack of skills of equipment and chemical substance ➢ Cannot identify science question ➢ Cannot propose the ways to solve problems. ➢ Have no plan on working included do the experiment without planning.	35.89

TABLE 16 (continued)

Themes	The example of quotations referred in each theme	Findings (%)
	➢ Cannot identify the purpose of experiment and do not know what they do even they enjoy doing the experiment ➢ Cannot discuss the results and cannot make the conclusion ➢ Write in a meandering fashion when making conclusion even they understand how to do the experiment	
(ii) Lacking on language abilities	➢ Lack of ability in reading and reading comprehension when given science article ➢ Low achieving students need a longer time learning and they were false on spelling	5.13
(iii) Student behavior	➢ Less concentrated on learning, Less effort ➢ Less attention while doing the experiment, Lack motivation in learning, Less confident to do the activities, Students late handing assignment ➢ Talking too much in the classroom ➢ Using mobile phone ➢ Did not submit science task	38.46
(iv) Lacking Science laboratory equipment	➢The tools and equipment for enhancing science skills were limited. ➢ Lack science equipment, teacher demonstrated the lab instead. ➢ The equipment was not enough; therefore, the class could not complete the experiment. The video clip was used instead. ➢ Malfunctioned science equipment	10.26
(v) Curriculum	➢ The content related to mathematics was not paralleled with science content. Therefore, science teacher need to teach some content of mathematics for applying to science question i.e. square root.	10.26

TABLE 16 (continued)

Themes	The example of quotations referred in each theme	Findings (%)
(v) Curriculum	➢ The amount of content was not suitable for timing; as a result some experiments were skipped. ➢ Science content was not sequenced in order.	

According to Table 16, Findings, the highest was problem related students' behavior (38.46%) and the second was students' lacking of science process skills and less awareness while doing the experiment (35.89%) while problems related to students' language ability (5.13%), lacking of laboratory equipment (10.26%) and curriculum (10.26%) were revealed. Although problems related to students' behavior was found the highest rated problem it had many factors affecting and needs long time to shape and change. Therefore, the researcher continued to solve the problem related to students' awareness while doing the experiment and lacking of science process skills. Refer to table 16, it indicated that students lacked science process skills such as; measuring, formulating hypotheses, experimenting, interpreting data, and communicating. In terms of "cannot identify the purpose of experiment and do not know what they do, no plan working, wrong procedure on the experiment" are demonstrated students less awareness while learning or they have less reflect while learning. In addition, it had showed students had less interest and responsibility in science as well as lacking of science laboratory equipment in schools.

In this study, researcher continued to solve the problems relate to students lack of science process skills and less awareness while learning.

1.2 Results of an exploration of secondary school students' level of science process skills in Bangkok

As the teachers' opinions had mentioned about students' lacking of science process skills leaded to a collection of data from 426 lower secondary school students which were consisted of 189 of seventh grade, 113 of eighth grade, and 124 of ninth grade students from five schools in Bangkok during August – September 2017 for exploring about students' level of science process skills abilities by the test which was created by the researcher. It was forty items in the test consisted of both basic and integrated science process skills. Data were analyzed by mean score and percentage to find students' level of science process skills.

The researcher set at 45% and 65% of full score to category into three levels; low, moderate, and high where upper than 65% of total score was high, lower than 35% of total score was low and mean score between 45 – 64% of total score was moderate level. The findings revealed that lower secondary school students almost were placed at a moderate level. There were 8 skills that students were placed at moderate level namely observing (47%), classifying (50.5%), using space/time relationship (56.3%), using number (55%), inferring (58%), defining operationally (52.7%), interpreting data (59.3%), and identify and controlling variables (49%). There were 3 skills that students placed at high level namely measuring (69%), communicating (78%), and predicting (66%) see Figure 21.

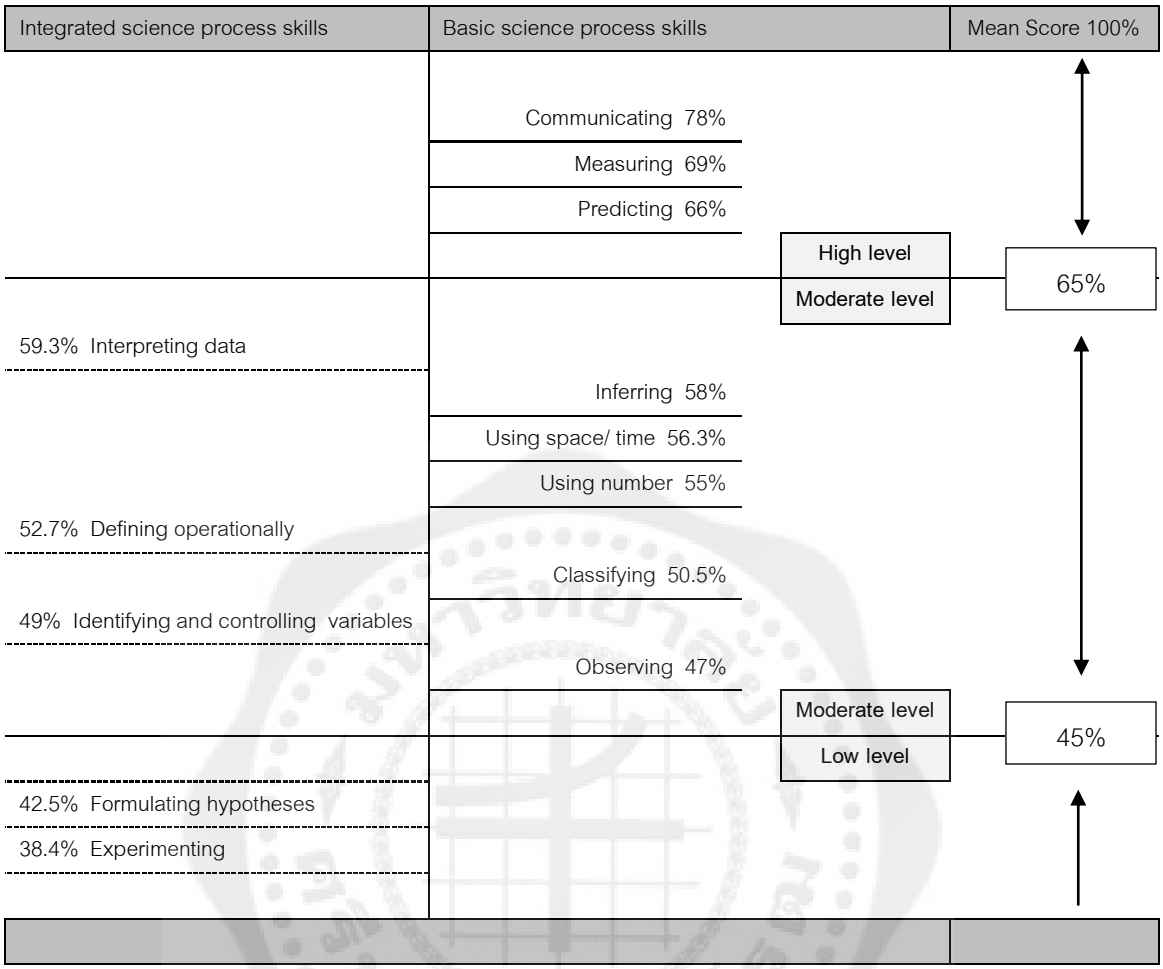

FIGURE 21 An exploration of secondary school students' level of science process skills in Bangkok (semester 1 of 2017 academic year)

According to the results of the survey showed that students have placed at low level on formulating hypotheses (42.5%) and experimenting (38.4%). Therefore, the learning activities in this study were focused on these skills which students could integrate other skills as well.

Section 2: The results of learning model development

As the main problem needed to be solved was that students' were lacking in science process skills and were less aware while doing the experiments which lead to the development of the learning model in this study. After evaluated by experts and did a pilot

study, it could be concluded the results of evaluation and processes of learning model development as following;

Background

According to teachers' opinions revealed that students lacking in science process skills and no working plan which affect doing wrong procedure and cannot reflect purpose of experiment. That demonstrated students had less aware while learning and they needed more plan and needed to set the goal of experiment or task through the goal of each procedure, needed to monitor its proceeding that would keep students concentrated or were on the path of procedure. Moreover, lacking of science process skills had found in previous studies both lower and upper secondary school students (Chaiyen; Bunsawansong ;& Yutakom. 2007; Kaewseehabut ;& Khantho. 2007; Nakthong; Anuntasethakul ;& Yutakom. 2007; Chairam; Klahan ;& Coll. 2015; Kruea-In; & Fakcharoenphol. 2015; Somsuk. 2015) As science process skills were important in having a science education (Harlen. 1999) and illustrated in terms of using process skills in science competencies of PISA framework measurement. In order to develop students' science process skills the previous studies had showed that inquiry learning was used effectively (Şimşek; & KabapÕnar. 2010; Koksala; & Berberoglu. 2012; Lati; Supasorn; Promarak. 2012; Yadav; & Mishra. 2013; Aydoğdua; Buldur; & Kartal. 2013; Ogan-Bekiroğlu; & Arslan. 2014; Chairam; Klahan;& Coll. 2015) however the students were aware while learning what needed to be solved in this study. Consequently, this learning model was infused between inquiry learning approach and metacognition in terms of regulation of cognition (metacognitive strategy) for enhancing students' science process skills and students' perceived during on learning path. Students would be learned not only process skills but they were also aware what the goal is, know what they do, and checking what they know and do not know. In other words, students' perceived on learning path was hypothesized that could improve students' self-efficacy in science had consistent with their performance. As the PISA 2006 had reported that self-efficacy in science of Thai students had not correlated with achievement; they had high mean score of self-efficacy but low mean score of achievement. Finally, it therefore summarized that the metacognitive strategy embedded in inquiry learning model was

developed in order to enhance science competencies, science process skills and self-efficacy in science.

Theory/principle

The principle of metacognitive strategy embedded in learning inquiry model was infused between inquiry learning approach and metacognition in terms of regulation of cognition. In terms of inquiry based learning approach, inquiry was an active learning process which engaged students learning with meaningful dialouge (NESE cited in Anderson. 2002; Barrow. 2006: 266). Scientific inquiry was at the heart of science and science learning, there were five essential features that apply across all grade levels – 1) engaged in scientifically oriented questions 2) gave priority to evidence in responding to questions 3) formulated explanations from evidence 4) connected explanations to scientific knowledge 5) communicated and justified explanations. However, these five features had four levels of inquiry. It was varied from less self-direction to much self-direction which teacher could design and chose to suite students learning experiences (NESE.1996; NRC.2000). In this learning model, 5E inquiry was used and students would finally be achieved each feature of inquiry in each phase of 5E step by step which was as following; engagement, exploration, explanation, elaboration, and evaluation respectively. According to Schraw et al (1995; 2006) had defined metacognition as the ability to reflect upon, understand (knowledge of cognition), and control's one learning (regulation of cognition). Thus, regulation of cognition was required to enhance students to be aware and control while learning. Regulation of cognition referred to a set of activities that help students to control their learning. It comprised of three components included 1) planning (P)—related to the selection of appropriate strategies and allocated of resources to be successful on tasks 2) monitoring(M)—referred to one's on-line awareness of comprehension and task performance including engaged self-testing while learning 3) evaluating(E)—referred to appraising the products and regulatory process of one' s learning. In terms of regulation of cognition—P-M-E was used as sub cycle in each E phase included engagement, exploration, explanation, and elaboration. In other words, regulation of cognition was driven

the process of inquiry in order to enhance students to be aware what they did and attained the features of inquiry.

Purposes

To enhance students' science competencies, science process skills, and self-efficacy in science.

2.1 The results of evaluation of the learning model by experts

The metacognitive strategy embedded in inquiry learning model was developed in order to focus on students' regulation themselves while learning inquiry. The steps of the learning model were shown in Chapter 3. The second draft of learning model consists of eight parts; 1) Background 2) Principle 3) Purposes 4) Learning process 5) Objectives and roles of teacher and student and 6) Contribution. It was evaluated by three experts to check the validity in terms of Index of Consistency (IOC). The lists of evaluation on each item in part 1 related to the reflection of infusing of inquiry learning and regulation of cognition in terms of; 1) the features 2) steps or learning processes 3) the features and learning processes of learning model enhancing science process skills 4) the features and learning processes of learning model enhancing science competencies 5) the features and learning processes of learning model adjusting self-efficacy in science.

The lists of evaluation on each item in part 2 related to the appropriateness of implementation in the classroom in terms of teacher's role, students' roles and purposes in each phase; engagement, exploration, explanation, elaboration, and evaluation.

The result of evaluation on Index of Consistency (IOC) of the metacognitive strategy embedded in inquiry learning model in each item was between 0.67 – 1.00 for more detail was showed in APPENDIX B.

The experts gave comments and suggestions to improve the learning model was that in terms of too much focusing on metacognitive regulation (planning-monitoring-evaluating) leaded to be careless on five features of inquiry. Researcher then demonstrated more clearly on five features of inquiry as the goal in each phase of learning even students were learning based on step of planning-monitoring-evaluating, they finally aimed to attain

the features of inquiry. Based on the experts' suggestions, researcher adjusted learning activities by giving more time to inferring data/evidence and engaged students to think and make the explanation based on the evidences from the experiment. Moreover, the translation of "self-efficacy in science" in Thai was changed.

Additionally, the experts gave the comments and suggestions to improve the learning model: *1) in terms of too much focusing on metacognitive regulation* (planning-monitoring-evaluating) which lead to being careless on five features of inquiry. The researcher then demonstrated more clearly on five features of inquiry as the goal in each phase of learning even students were driving based on step of planning-monitoring-evaluating, they finally aimed to attain the features of inquiry. *2) In exploration phase;* the researcher improved by giving more time to inferring data/evidence. *3) In explanation and elaboration phases;* the vague of process features between inquiry learning and the metacognitive strategy embedded in inquiry learning model was asked by an expert; "were the learning model the same as inquiry learning?" the researcher then showed its difference in the lesson plan; inquiry feature was similarity as the step of planning-monitoring-evaluating was hidden in the overview of inquiry learning but it was not identified clearly step by step and clearly evidence like the metacognitive strategy embedded in inquiry learning model. Because every phase with regulation of cognition of the learning model had to write a plan clearly and used this plan as a checklist to monitor while on process and also checking via discussion/ others' presentation and finally students evaluated/ made decision to complete explanation or given tasks. *4) In evaluation phase*; the comment of the expert leaded researcher adjusted the learning activities by balancing between students' self-evaluation and the measurement of learning objectives by teacher. Finally, the translation of "self-efficacy in science" in Thai was changed. The expert suggested that focusing on planning-monitoring-evaluating is good for teachers if we could make its harmony linkage structure of the metacognitive regulation and 5E inquiry. However, timing was concerned that leaded researcher more considering and adjusting the pattern of ISNs notebook and asking students instead of writing the plan in some activities. Based on suggestions and pilot study had shaped the final feature of learning model and was showed as Figure 22

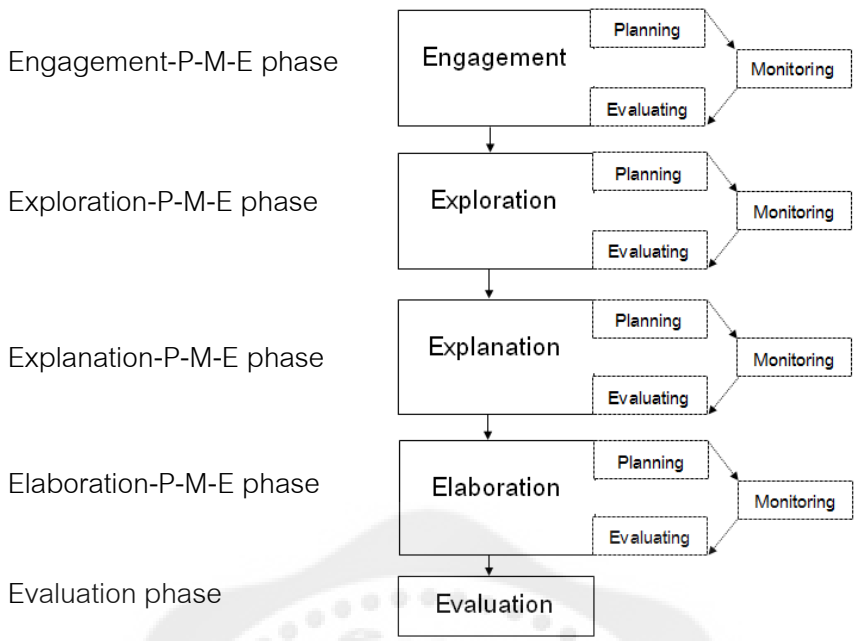

FIGURE 22 The metacognitive strategy embedded in inquiry learning model

2.2 Description of the metacognitive strategy embedded in inquiry learning model

The learning model was adjusted based on all the comments from the experts and the data from a pilot study. The metacognitive strategy embedded in inquiry learning model finally consisted of five phases and was showed in details in each step of regulation of cognition. The main question in planning step was related to what is the goal, what I know, what I do not know, what I need to know, and how to know/do. These questions could help students both regulation in process and could be extended to connect to the testable question, variables when students needed to do the experiment. The figures below were shown to describe how processes were driven; —the left side of each figure was the feature of inquiry that students would get it when they completed that phase, while the metacognitive strategy (cognition of regulation) namely planning-monitoring-evaluating were shown the main activity and questions to attain each phase.

2.2.1 Engagement-P-M-E phase: this phase was aimed to enhance students' abilities to make a plan, monitor, and evaluate their abilities and prior knowledge. Therefore, students needed to be asked and evaluated their prior knowledge while discussion their ideas with friends, making plan, and responding to given learning activities, questions as

well as teacher promoted students' interested in science question and students engaged in scientifically oriented questions to formulate science question (testable question).

Students were engaged by instructional material such as pictures, clip video, news, phenomena, and events that could be connected with new science concept they would learn. Students used and evaluated prior knowledge related to those instructional materials. Students interested in some issues related given instructional materials, proposed questions and discussed what they were curiosity in those situations, considered about resources or time and reached the main question to explore. In term of experiment activity, that main question was changed and planned to become a testable question. Students asked themselves; what I know, what I do not know to be the key when formulating the testable question. Checking the question by checklist of testable question component and clarify via whole class discussion. Based on the discussion, students evaluated and fulfilled the final testable question. Teacher's role was to prepare the instructional materials, questioning students sometime to know their prior knowledge and being as a facilitator; scaffolding students by questioning or using sign.

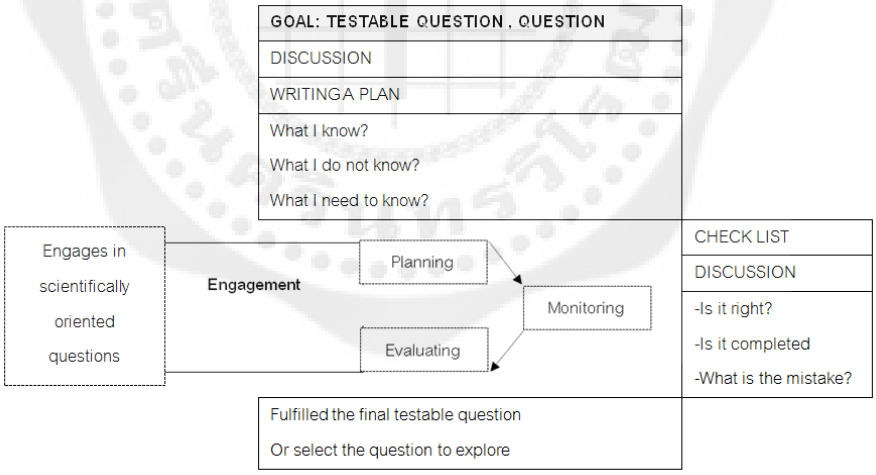

FIGURE 23 Details in engagement-P-M-E phase

2.2.2 Exploration-P-M-E phase: this phase aimed to enhance students in being able to make a plan, monitor, and evaluate their procedures to attain the required evidences. Students perceived their capabilities to making plan and exploration. Therefore, students needed to be asked and evaluated their knowledge and skills while discussion their ideas

with friends, making plan, and responding to given learning activities as well as students gave priority to evidence in responding to question.

Students set the main question/ testable question as a goal to find out the answers. Students identified the needed evidence/data and proposed the ways to get those needed evidence/data based on students' experience by everyday language. Discussed and completed the writing plan in order to get the evidences before doing the experiment/explore. Using the ISN notebook as the writing plan and recording data sheet when doing the experiments. Students transferred the experiment plan in ISN notebook from everyday language (on left side) into science terminology (on right side); hypothesis, variables, and defining operationally variable. Continuing checked the consistent among plan, goal, and procedure while doing experiment/exploration/task via checklist. Discussed about the results/data; comparing and inferring. Students evaluated the evidence and all the results, inferring evidence/data, mistake. The teacher's role was to prepare the instructional materials, being as a facilitator; engaged students to monitor the procedures, questioning/listening and clarifying about indicators and processes that students proposed or discussed by every language.

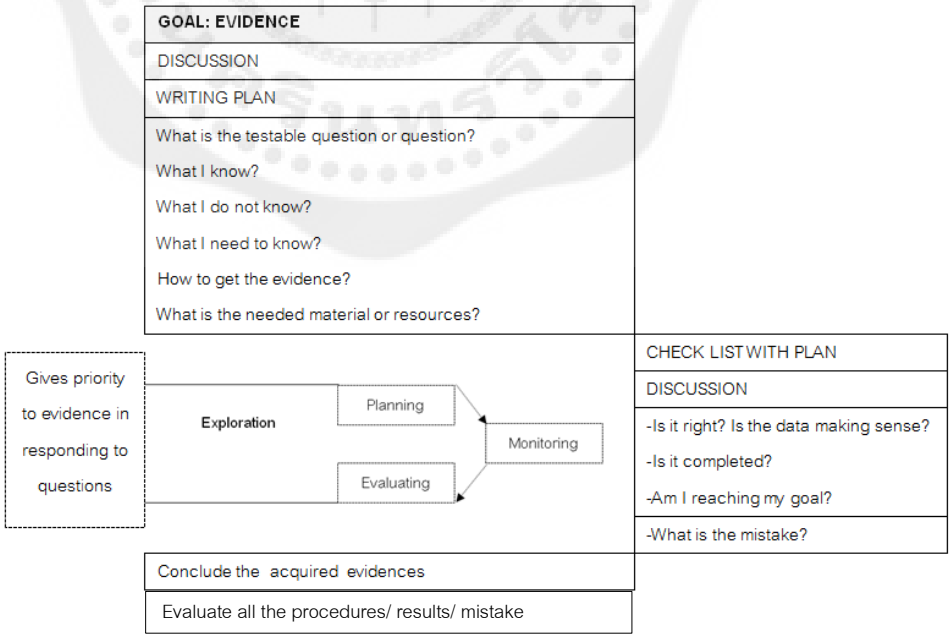

FIGURE 24 Details in exploration-P-M-E phase

2.2.3 Explanation-P-M-E phase: this phase aimed to enhance students were able to make a plan, monitor, and evaluate their scientific explanation. Students perceived their abilities in formulating the explanation from evidence, connecting explanation to scientific knowledge, and communicating and justifying explanations. Therefore, students needed to be asked and evaluated about their knowledge while discussing their ideas with friends, making plans, and responding to given learning activities.

Students gave priority to the explanation based on the evidence. Students connected the evidence or phenomena to science knowledge that they had learned or new knowledge. Discussed and interpreted data or experiment results. Planning to make conclusion and scientific explanation were started by recall the goal and evidence required which were planned. Students asked themselves; what I know, what I need to know to be the key when formulating the scientific explanation. Students made conclusion and scientific explanation by using explanation template/guidance. Students checked the explanation via the checklist and whole class discussion. They evaluated and made decision to fulfill the explanation. Teacher's role was being as a facilitator; reminded students to plan the formulating of explanation and monitoring the process, given students' opportunity to make discussion and presenting their ideas, listening and questioning, checking misconception, clarifying students' language, and giving new science concept.

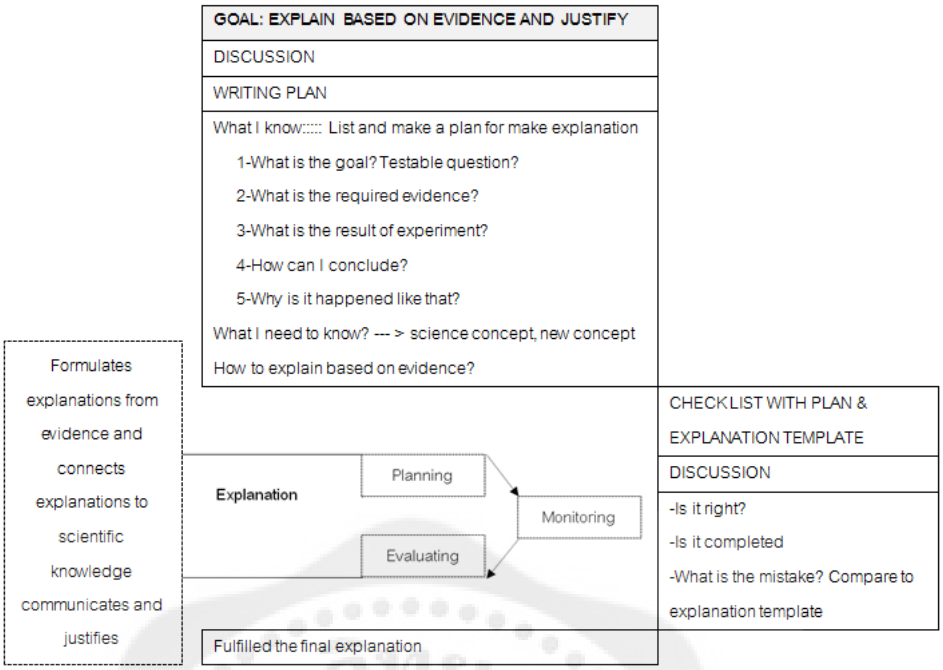

FIGURE 25 DETAILS IN EXPLANATION-P-M-E PHASE

2.2.4 Elaboration-P-M-E phase: this phase aimed to enhance students were able to make a plan, monitor, and evaluate the applying of knowledge and skills they had learned to solve the problems or science tasks; criticizing news, experimental, explaining scientific phenomena, and so on. Students perceived own abilities both knowledge and skills including realized about the fruitfulness of scientific contribution. Therefore, students needed to be asked and evaluated their knowledge and skills while discussion their ideas with friends, responding to the science task such as formulating testable question/goal, exploring the evidence and formulating the explanation based on evidence, connecting explanation to scientific knowledge including communicating and justifying explanation.

Students applied science knowledge and skills they had learned; set the goal of assigned science task, made all the plans to attain—testable question, data/evidence, and using science knowledge to explain phenomena or other situations scientifically. Teacher's role was to prepare the instructional materials/ science task and being as a facilitator; given students presented their ideas, scaffolding sometime, checking misconception.

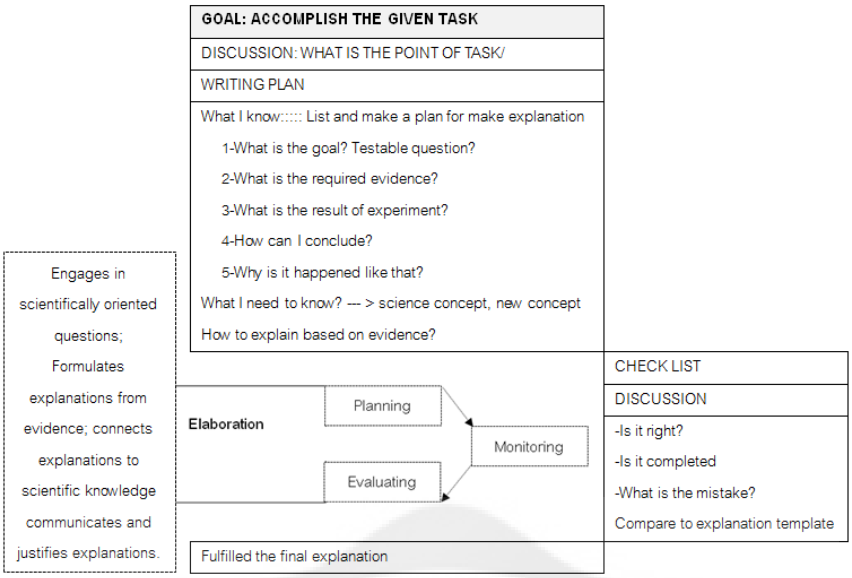

FIGURE 26 DETAILS IN ELABORATION-P-M-E PHASE

2.2.5 Evaluation phase: this phase aimed to evaluate students' knowledge and skills. Students perceived own abilities both knowledge and processes as students needed to respond to the questions, worksheet and self-evaluation form about their gained knowledge and skills. In other word, students perceived their capabilities related to learning concept and learning ability they experienced which affected to level of self-efficacy in science.

Students were measured all knowledge and skills they had learned through questions, worksheet, journal, and self-evaluation form in terms of reflection what they had learned by comparing knowledge and skills between pre- and post- learning activity.

TABLE 17 Overview and roles of teacher-student in each phase

Overview	Sub cycle	Student' s role	Teacher' s role
Engagement Enhancing students were able to make a plan, monitor, and evaluate while learning and perceived own abilities both knowledge	Planning	1) response to pictures/ situation/ simulation/clip video/news/daily life which are presented by teacher 2) recheck prior knowledge relate to those presentations 3) propose the questions or	1) prepares learning material such as pictures/ situation/ simulation/clip video/news/daily life 2) questioning to know students' prior knowledge 3) giving the example of

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
and processes as students needed to be asked and evaluated their prior knowledge while discussion their ideas with friends, making plan, and responding to given learning activities. In addition, students interested in science question and engaged in scientifically oriented questions to formulate science question (testable question).		issues that they want to know or investigate 4) consider data from issues what they already know and what they have not known yet to formulate testable question (scientific question) or goal of investigation	testable questions to students and engage them to pinpoint of those questions 4) engage students to create the testable question; based on the question they have what you already knew, what you have not known yet.
	Monitoring	1) Propose the testable question or questions relate the presented material and discuss 2) Check and compare the formulated testable questions with others 3) Consider identifying the companion of the formulated testable questions or the questions that can be learned belong to the resources at that time.	1) Shows students the comprising of testable question for monitoring themselves. 2) Being as a facilitator
	Evaluating	1) evaluate all the testable questions presented in monitoring step and make decision to write the final testable question/ or questions that needs to continue investigation.	1) helps when students need to scaffold; edit students' language in sentences (clarifying)

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
Exploration enhance students were able to make a plan, monitor, and evaluate while learning and perceived own abilities both knowledge and processes as students needed to be asked and evaluated their knowledge and skills while discussion their ideas with friends, making plan, and responding to given learning activities. In addition, students gave priority to evidence in responding to question.	Planning	1) Identify the goal of investigate 2) Identify the evidences which can be confirmed and consistent with the testable question/ or the goal of investigate 3) Plan to get that evidence based on asking themselves/guided; what does the material need to use? How to get the evidence? What is the indicator to collect the evidences? Can it measure by number? What is the careful acting while doing the experiment?	1) Reminds students about their goal/the testable question that they are going to pursuing 2) Being a facilitator while students are discussing about the procedure plan include gives students sometime the questions to enable the complete plan 3) Listens and adjusts students' identifying the instruments or indicators include the procedures of doing experiment that proposed by students' experiences.
	Monitoring	1) Checking between plan and procedure while doing the experiment 2) Checklist on ISNs notebook about getting the evidences, error, problems occur while doing the experiment by answer the questions as following; -Do I reach the evidences? -Do I find something wrong? -What is the problem? -Is it right procedure? -Is the data making sense?	1) Engages students to monitor while doing the experiment by checklist; got evidence yet? On the right path? 2) Being a facilitator
	Evaluating	1) Evaluate the evidences 2) Compare the results of experiment or data with others 3) Recommend what they want to	1) Engage students to evaluate the evidences from the experiment including find factors

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
Exploration		continue to investigate next. 4) Give suggestions about the experiment	affecting error in the experiment 2) Helps when students need to scaffold; being a facilitator 3) Ask students what they do recommend or want to continue to investigate next.
Explanation Enhancing students were able to make a plan, monitor, and evaluate while learning and perceived own abilities both knowledge and processes as students needed to be asked and evaluated their knowledge while discussion their ideas with friends, making plan, and responding to given learning activities. In addition, students formulated explanation from evidence, connected explanation to scientific knowledge, and communicated and justified explanations.	Planning	1) Recalls the goal of investigation to be the path to use the evidences response to question in engage phase. 2) Compare and interpret the results from experiment and the expected evidences 3) Discuss about the experiment results 4) Lists the scientific principles relate to the experiment results for making explanation of those results.	1) Reminds students about their goal/the testable question that they are going to pursuing 2) Being as a facilitator while students are discussing about the experiment results including gives students the questions to enable the learning objectives 3) Listens and adjusts the alternative concept about students' opinion including their explanation about the results that proposed by students' experiences/own language which might be casual language and need to connect to scientific concept. 4) Writes the main point/ scientific concept that students already discussed relate to the

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
Explanation			experiment on the blackboard 5) Checks students' misconception and understanding
	Monitoring	1) Write the conclusion and explanation of the experiment/exploration and checklist with the goal or the template plan of scientific explanation 2) Compare those conclusion and explanation with others	1) Reminds students to monitor while writing the explanation by checklist 2) Gives students opportunities to presents their writing 3) Listen and being as a facilitator 4) Ask more details about words in the paragraph of explanation to check misconception.
	Evaluating	1) Evaluate and make decision by comparing and making perfect explanation with own language.	1) Engages students to evaluate and make decision to be complete explanation 2) Adjusts the casual language to formal 3) Recall the questions or situations that mention at the engage phase to students in order to connect and to be revealed 4) Presents other contexts or more details that relate to the experiment results

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
Elaboration Enhancing students were able to make a plan, monitor, and evaluate while learning and perceived own abilities both knowledge and processes as students needed to be asked and evaluated their knowledge and skills while discussion their ideas with friends, making plan, and responding to the science task. In addition, students formulated testable question/goal, explored the evidence and formulated the explanation based on evidence, connected explanation to scientific knowledge including communicated and justified explanation.	Planning	1) Set the goal 2) Identify what can be the important data or evidence to be the answer of question. 3) Propose the way to get data or evidence and identify the resources	1) Prepares instructional material such as pictures/ situation/ simulation/clip video/news/daily life / work sheet/ science task 2) Engage students to set/identify the goal and the ways to get the evidence/ data to use in solving those assigned science tasks such as; What is the goal? What is the needed data to make you reach the goal? Where/How to get those data? How is the needed data relate to the question?
	Monitoring	1) Reminds the goal to check; Is it complete data? How is it related? 2) Proposes and compares the ideas with others	1) Being as a facilitator 2) Reminds the goals to the students 3) Gives scaffold sometime 4) Gives students opportunities to presents their ideas and listen them 5) Ask more details about words students use in order to check misconception.
	Evaluating	1) Evaluate and make decision by comparing and making perfect answer	1) Engages students to evaluate and make decision to be complete the task.

TABLE 17 (continued)

Overview	Sub cycle	Student' s role	Teacher' s role
Evaluation Evaluating students' knowledge and skills. Students perceived own abilities both knowledge and processes as students needed to be responded to the worksheet and were evaluated themselves about their gained knowledge and skills. In other word, students perceived their capabilities related to learning activities they experienced which affected to level of self-efficacy in science.	-none-	1) Self-evaluation in terms of reflects what they have learned comparing between pre- and post-learning activity and write the journal sometime. 2) Response to the given measurement task	1) Prepares learning material such as pictures/ situation/ simulation/clip video/news/daily life / work sheet 2) Listen, observe students while doing given measurement task 3) Given students task or test in order to measure learning objectives. 4) Given students positive feedback with focusing on effort, tell them what good things they have and what should be more consideration and practice.

Section 3: The results of learning model implementation and evaluation

3.1 Context

The evaluation of learning model was conducted at a School in Bangkok during January – February 2018. As the school policy had just changed in the middle of November, 2017; gathering two classrooms into the big one class in some subjects. It affected to 43 students were mixed from the moderate learning ability of M.1/1 and M. 1/3 which students were mostly slow learners in the same science classroom. Students were grouped by mixed ability based on their same original classroom. There were 4-5 students in one group. However, some of them would not complete some tests or they missed the class too many times and as a result the total of students were calculated the statistic was

only 33 students. The context of school was found like the previous findings of teachers' opinions related the problems in the science classroom in many aspects;

The students in the class were much different in terms of prior knowledge, less ability in language, the difference of abilities in learning and problems related behavior such as talking too much and using mobile phone in the classroom had found. Classroom management was also different from a pilot study. A few students were open-minded to the feedback from the teacher and whole class discussion fulfilled their explanations. Less attention had found especially in the post-test; most students finished the post-test in only 15-20 minutes which was less than pre-test.

In terms of the facilities in the classroom was limited such as LCD television which was small and affected to the effectiveness of using ICT in learning activities and students' concentration while learning. Lacking of laboratory equipment had found.

School activities were a lot like the general school but it affected to change the schedule from the first meeting which affected to the time was less than the IPST curriculum for two hours and separated period. Therefore, the summative assessment was rearranged to the last day of school examination week. Researcher had to run the learning activities in some topic quickly and measure learning objective based on observation instead of checking their worksheet. In term of the test format in each subject in school, they had only multiple choices and matching/ short answer. It was hardly to see the writing test even in Thai subject.

3.2 The effectiveness of learning model

3.2.1 Students' science process skills

To find the results, students had one hour to complete the test before and after using the learning model. The test was paper-pencils test type consisted of basic process skills 24 items (24 marks) and integrated process skills 16 items (16 marks). The results were shown in Table 18.

TABLE 18 The comparison between pretest and posttest score of students' science process skills

	n	$\bar{X}$	S.D.	t	p
Pretest	33	18.73	6.40	0.796	0.432
Posttest	33	18.15	5.99		

Table 18, the posttest was not statistically significantly higher than pretest at .05 level. The finding was quite unusual due to the students completed the posttest only 15-20 minutes and the test was done in the last period of long testing whole Friday day which was different from pretest that had done in the first period of the day and students completed it almost one hour. In other hands, they were less attention when doing the posttest compared to the pretest.

In addition, based on the informal interview, students were asked the questions related to what students had learned from the using of learning model, the difficulties they had faced while learning, the appropriateness of using the learning model, and students' satisfactions to the learning model and learning activities.

Students reflected that using the metacognitive strategy embedded in inquiry learning promoted gain in science process skills and planning the experiment. Example quotations were shown as following;

"Testable question was my new word, consisted of dependent and independent variables, we could formulate by using the word 'affect" to connect however they could be written in various type but showing the variables" (SG3)

"I had never know the word "testable question" (SG4)

"We could apply testable question in science project" (SB2)

"I had just known the defining operationally; it was the definition of the word had to show criteria" (SG5)

"Previous teacher did not have the step of planning just overview" (SG6)

"It had the objective and testable question to do the experiment that was different from my previous experience" (SG3)

Additionally, making plan leaded students were conscious on procedures. Example quotations were shown as following;

"Having the step of planning leaded me feel more understanding" (SG5)

"The plan in left side was helpful for me" (SB3)

"Easy to understand, it made me know what I had to do or I had to do this" (SG4)

"I could create the plan, but if the cookbook sheet was already created by teacher" (SG5)

However, a student reflected that making plan was not helping her consciousness on procedure.

"It helped me just a little" (SG6)

3.2.2 Students' science competencies

Finding, the post-test of science competencies was statistically significantly higher than pre-test at .05 levels. The statistic was shown in table 19.

TABLE 19 The comparison between pretest and posttest score of students' science competencies

		n	Full score	$\bar{X}$	S.D.	t	p
Overall	Pretest	33	22	8.39	2.235	-2.108	.043*
	Posttest	33	22	9.18	2.899		
Explain Phenomena Scientifically	Pretest	33	9.00	3.70	1.075	.452	.654
	Posttest	33	9.00	3.61	1.345		
Design Scientific Enquiry	Pretest	33	5.00	2.61	0.933	-1.299	.203
	Posttest	33	5.00	2.88	0.781		
Interprets Data and Evidence Scientifically	Pretest	33	8.00	2.12	0.927	-3.288	.002*
	Posttest	33	8.00	2.73	1.281		

*p < .05

Table 19, the overall of science competencies post-test was statistically significantly higher than pre-test at .05 level.

There was no statistical significant difference between pre-test and post-tests at .05 level on explain phenomena scientifically. The amount of students who placed higher than 50% of full score was same. These are unusual findings. It might because the students' reading comprehension or students' attention while doing the post-test because the post-test was done on the last day of examination week in second semester. Students completed the post-test so quickly and may have not be dedicating themselves to it as they could have.

There was no statistically significant difference between pre-test and post-test at .05 level on design scientific enquiry.

It was statistically significant difference between pre-test and post-test at .05 level on interprets data and evidence scientifically.

In addition, based on informal interview, students were asked the questions related to the difficulties they had faced while learning. Students reflected that they had problems related to writing. It indicated that students' ability in language might affect to their science competencies because the test required students to comprehend, use the information in paragraph, and response by writing justifying. Example quotations were shown as following;

"I had problem in writing" (SG5, SB1)

"I could not reflect my though in writing, it was less than my though" (SB3)

"When I wrote my thought was changing more and more, I liked to explain the particular topic given from teacher rather than explain what I had gained knowledge" (SG6)

"Self-evaluation leaded me perceived I had gained knowledge from the lesson but I sometimes could not write it however I knew that I had gained more knowledge than before" (SG4)

However, some students reflected that time was a condition for practicing their writing skills.

"I was not familiar with writing on worksheet if doing more, it would be more familiar" (SB7)

"In beginning I could not reflected as my though but later it was better" (SG4)

3.2.3 Students' self-efficacy in science

The comparison of students' self-efficacy in science between pre- and post-test was shown below in Table 20

TABLE 20 The comparison between pretest and posttest score of students' self-efficacy in science

	n	$\bar{X}$	S.D.	t	p
Pretest	33	2.93	0.35	-2.999	0.005*
Posttest	33	3.25	0.49		

*p < .05

Table 20, the students' self-efficacy in science posttest was statistical significantly higher than pretest at .05 level.

In addition, based on the informal interview, students were asked the questions related to what students had learned from the using of learning model, the difficulties they had faced while learning, the appropriateness of using the learning model, and students' satisfactions to the learning model and learning activities.

Students reflected that they were confident on experimental planning and science process skills. Example quotations were shown as following;

"I could create the plan, but if the cookbook sheet was already created by teacher" (SG5)

"Talking before doing the experiment made me more understanding" (SB2, SB7, SG6)

"It made me more understanding; there had the objective and testable question to do the experiment that was different from my previous experience" (SB1)

"Easy to understand, it made me knew what I had to do or I had to do this" (SG4)

"The humidity experiment was reality situation and I could measure it, I had just known that the level of relative humidity was depended on place, temperature" (SG4)

Furthermore, students demonstrated that they had positive attitude with using the learning model.

"I liked it, informally planning" (SG5)

"I liked humidity experiment because it was reality situation" (SG4)

"I liked the balancing bag because it was fun; I had just known that heat made the bag become lighter" (SB2)

"I liked the experiment of balloon in hot water because it was challenging me to measure the size, it needed to quickly measure because it shrinked quickly. Even I used to see the extension-shrink of food bag but I never knew why it happened but this experiment made me knew that because of the air pressure" (SB1)

Students also recommended that the context of classroom atmosphere and students' character were the important condition to be considered before using the learning model and quietness atmosphere was required by certain students.

"It was appropriateness to use in secondary school students" (SB1, SB3, SG4, SG5, SB7)

"It was appropriateness to use in secondary school students however depends on students" (SB2)

"The learning model suited for students who was attention in learning and the class had not noisy but our school did not" (SB2, SG5)

"I required high concentration while learning by this learning model" (SG6)

"Using this learning model was not required high concentration for me" (SG4)

"Friends made talking affected to my concentration while learning" (SB2, SG6)

"This learning model should be used even students made noisy but find the way to make them be quiet" (SB2, SB3, SG4, SG5)

3.2.4 The correlation between students' science process skills and science competencies.

Pearson's correlation was calculated to find the correlation between science process skills and science competencies on posttest. The scatter graph was shown as Figure 27.

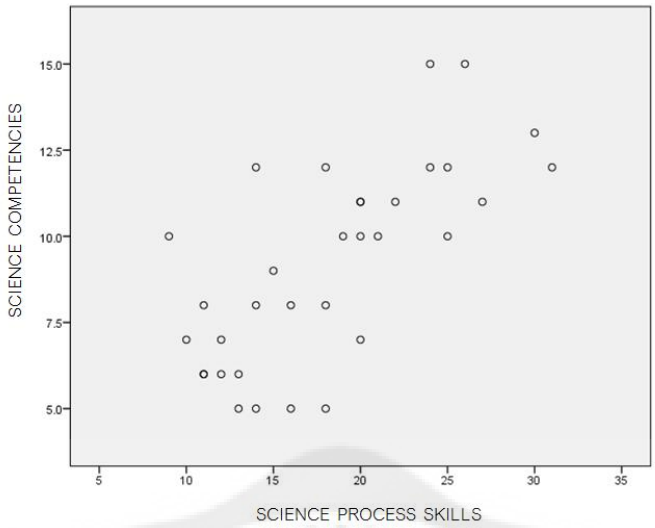

FIGURE 27 The scatter graph of correlation between science process skills and science competencies

Figure 27, it demonstrated that the scatterplots had positive correlation; both science process skills and science competencies moved in the same direction. In other words, as science process skills increased science competencies also increased. As science process skills decreased science competencies also decreased. Moreover, Pearson's correlation has shown in Table 21.

TABLE 21 The Pearson correlation between science process skills and science competencies

		science process skills	science competencies
science process skills	Pearson Correlation	1	.704**
	Sig. (2-tailed)		.000
	n	33	33
science competencies	Pearson Correlation	.704**	1
	Sig. (2-tailed)	.000	
	n	33	33

** Correlation was significant at the .01 level (2-tailed).

Tables 21, it had found the correlation between science process skills and science competencies; Pearson's correlation is .704 on posttest. It was high correlation between science process skills and science competencies.

3.2.5 The correlation between students' science competencies and self-efficacy in science

Spearman's rho was calculated to find the correlation between science competencies and self-efficacy in science on posttest. The result was shown as Table 22

TABLE 22 The spearman's rho between science competencies and self-efficacy in science in pretest

POST-			Science competencies	Self-efficacy
Spearman's rho	Science competencies	Correlation Coefficient	1.000	.004
		Sig. (2-tailed)	.	.984
		n	33	33
	Self-efficacy	Correlation Coefficient	.004	1.000
		Sig. (2-tailed)	.984	.
		n	33	33

Tables 22, it had no correlation between science competencies and self-efficacy in science; Spearman's rho was .004 on posttest.

CHAPTER 5
CONCLUSION AND DISCUSSION

This chapter presented the conclusion of the study, discussion of research findings, limitation, and the recommendation for the further research.

Research objectives

1. To discover the problems based on science classroom in Thailand.
2. To develop the metacognitive strategy embedded in inquiry learning model.
3. To evaluate the effectiveness of a learning model on students' science process skills, science competencies, and self-efficacy in science.
4. To find the correlation between students' science competencies and science process skills.
5. To find the correlation between students' science competencies and self-efficacy in science.

Research questions

1. What problems are often found in the science classroom in Thailand?
2. What are the features of metacognition strategy embedded in learning inquiry model?
3. Does the metacognitive strategy embedded in inquiry learning model effect on students' science process skills, science competencies, and self-efficacy in science?
4. Do the students' science competencies have correlation with science process skills?
5. Do the students' science competencies have correlation with self-efficacy in science?

Research hypotheses

1. The metacognitive strategy embedded in inquiry learning model effected on students' science process skills, science competencies, and self-efficacy in science

1.1 Students' posttest score of science process skills was statistically significantly higher than pretest score at .05 level.

1.2 Students' posttest score of science competencies was statistically significantly higher than pretest score at .05 level.

1.3 Students' posttest score of self-efficacy in science was statistically significantly higher than pretest score at .05 level.

2. Students' science competencies had correlation with science process skills.
3. Students' science competencies had correlation with self-efficacy in science.

Research instruments

1. Science process skills test
2. Science competencies test
3. Self-efficacy in science test

Research methodology

This study was a research and development. The research was conducted since first semester of 2014 academic year for collecting the data of preparation stage which leaded to develop the metacognitive strategy embedded in inquiry learning model and research instruments and finally had evaluated the effectiveness of learning model in January 2018. The detail in each stage was as follows:

(1) The preparation stage: the data were conducted from two aspects:

1.1 Science teacher's opinions on science problems in science classroom by opened-questionnaire from schools across Thailand. The population included science teachers who taught the eighth grade students in public schools all over Thailand. There were 36 science teachers who taught the eighth grade students in public schools all over Thailand and were willing to respond to the given question from 36 schools located in nine

areas based on PISA Thailand criteria of sampling. The samples were selected by cluster random sampling.

1.2 The explorations of lower secondary school students' level on science process skills in Bangkok. The population was lower secondary school student in Bangkok is 230,101 students which were consisted of 116,526 boys and 113,575 girls in 2017 academic year. The samples were selected by using technique 5% of the Yamane formula, stratified random sampling and simple random sampling, respectively. They were 426 students which were consisted of 189 of seventh grade, 113 of eighth grade, and 124 of ninth grade students in Bangkok during August – September 2017 in first semester of 2017 academic year. These became the basic data leaded to the research title including emphasizing some process skills in the lesson plan.

(2) The developing learning model and research instrument stage

It was begun with review the literature to find out the previous study that could enhance students' science process skills and regulate students' awareness while learning. Finally, the learning model draft was developed based on 5E inquiry learning and metacognition strategy which consists of 1) engagement-P-M-E 2) Exploration-P-M-E 3) explanation-P-M-E 4) elaboration-P-M-E 5) evaluation. The result of learning model verifying by three experts had showed high appropriate level.

Research instruments were constructed by researcher which consisted of three tests as following:

1) Science process skills test consisted of forty items which are twenty-four items of basic science process skills and the sixteen items of integrated science process skills. The reliability (KR20) of the test was 0.83.

2) Science competencies test consisted of twenty-two items. The reliability (KR20) of the test was based on test format included: 0.42 for multiple choice, 0.53 for complex choice (true false), and 0.53 for writing (open-ended response), respectively.

3) Self-efficacy in science test consists of forty-one items created in Likert scale with five point scale. The Cronbach's alpha of the test was 0.91

The learning model with lesson plans and all research instruments were revised based on experts' comments and suggestions.

4) The pilot study: findings, some activities and instructional material had to adjust as follows:

- Using a technique of identifying students' name on the group picture and a big sign name of students in order to remember all students and make more effectively classroom management.
- Adjusting the ISNs notebook to compact and have less writing part.
- More considering on engaging students in writing. Formulated the example template of main context in the explanation paragraph to be the exemplar.
- Adjusting the wind experiment in order to make it clearly.
- Choosing the figure in terms of photo rather than drawing picture in Power point or worksheet.
- More considering in terms of students' misconception which could be adjusted by teacher's role had to check in monitoring step by more questioning and adjusting the ISNs by adding a part of before-after picture idea of matter changing in the experiment.
- Adjusting to less writing on worksheet or combined some activities, assignment as homework, discussing in whole class instead of small group, and presenting students' idea at their group table.
- Re-arranging the schedule.

(3) The evaluating stage

The complete learning model with nine lesson plans and all research instruments were proven the effectiveness of learning model developed on each. Hypotheses were tested and the results are concluded.

The population included seventh grade students in Bangkok. The participants consisted of thirty-three of seventh grade students from a school in Bangkok. Purposive sampling was used; they were students in public school, mixed achievers, had problems in

science classroom same as the results in stage 1. Data were collected during January – February 2018 which was in second semester of B.E. 2560 academic year.

Conclusions

The conclusions were presented based on the research questions as follows:

(1) The results of basic data

Firstly, an exploration of problems in science classroom revealed that students the highest was problem related students' behavior (38.46%) and the second was students' lacking of science process skills and less concern while doing the experiment (35.89%) while problem related students' language ability (5.13%), lacking of laboratory equipment (10.26%) and curriculum (10.26%) were revealed (seeing in Chapter 4 for more details). Although problems related to students' behavior had found the most but it is influenced by many factors and needs a long time to shape and change. Therefore, the problem related lack of science process skills and less concern oneself while learning was focused on this study.

Secondly, the exploration of lower secondary school students' level on science process skills in Bangkok. Findings, students mostly were at moderate level on basic process skills (mean score is between 45 – 64% of full score) and were at low level on integrated process skills (mean score less than 45 % of full score) however high level of process skills was found in terms of measuring (69%), communicating (78%), and predicting skills (66%). Consequently, these basic data leaded to step of investigating and developing the suitable learning model which could regulate students while learning as well as enhance students' science process skills. In addition, integrated science process skills become focusing process skills which are practiced through designing experiments following the learning model.

(2) The metacognitive strategy embedded in inquiry learning model

The metacognitive strategy embedded in inquiry learning model consisted of five phases includes;

2.1 **Engagement-P-M-E phase:** engage students by object, events etc. or those phenomena are connected with previous contents lead to evaluate prior knowledge related those situations. Students interest in some issues, propose questions and discussion what they are curiosity with in those situations and reach the main question to explore. Based on main question is planned to formulate a testable question by questions themselves. Checking the question by checklist of testable component and clarify via whole class discussion. Students evaluated and fulfilled the final testable question.

2.2 **Exploration-P-M-E phase:** give priority on evidence. Set the testable question as a goal. Identify the needed evidence/data. Propose the ways to get those needed evidence/data based on students' experience by everyday language. Discussion and complete all plans before doing the experiment/explore. Students clarify science terminology. Continue check the consistent among plan, goal, and procedure while doing experiment/investigation/task via checklist. Discuss about the results/data; comparing and inferring. Evaluate the evidence and all the results, inferring evidence/data, mistake.

2.3 **Explanation-P-M-E phase:** priority on explanation based on the evidence. Students connect those evidence or phenomena to science knowledge that they have learned or new knowledge. Recall the goal and required evidence which are planned. Discuss and interpret data. Plan to make explanation by using explanation template/guidance. Check through checklist and discussion. Evaluate and make decision to fulfilled explanation.

2.4 **Elaboration-P-M-E phase:** apply science knowledge and skills they have learned; the testable question formulation or ask question to be the goal of assigned science task, make a plan to attain data/evidence including use science knowledge to explain phenomena or other situations.

2.5 **Evaluation phase:** measure all knowledge and skills they have learned through questions, worksheet, journal, and self-evaluation in terms of reflect what they have learned comparing between pre- and post- learning activity.

(3) The effectiveness of the metacognition strategy embedded in learning inquiry model

3.1 Science process skills

Students' posttest score of science process skills was not statistically significantly higher than pretest score at .05 level.

3.2 Science competencies

The overall mean scores of science competencies posttest were statistically significantly higher than pretest at .05 level. However, in each competency revealed that the interpret data and evidence scientifically competency was statistically significantly higher than pretest at .05 level. Whereas the design scientific enquiry competency and explain phenomena scientifically competency were not statistically significantly higher than pretest at .05 level.

3.3 Self-efficacy in science

The students' self-efficacy in science posttest was statistically significantly higher than pretest at .05 level.

3.4 The correlation between science process skills and science competencies

There was correlation between science process skills and science competencies; Pearson's correlation is .704 on posttest. It was indicated that science process skills had strong correlation with science competencies. In other hand, students' abilities in science process skills had relationship with science competencies; high score of science process skills tended to enable high score of science competencies.

3.5 The correlation between science competencies and self-efficacy in science

There had no correlation between science competencies and self-efficacy in science; Spearman's rho was .004 on posttest.

Discussions

According to this research was originated due to the problems of students' lacking science process skills and less concern while learning in science classroom however students' science competencies and students' self-efficacy in science were expected to improve as a result researcher had developed the learning model and evaluated the effectiveness. Therefore, this part consisted of four parts discussion about the problems in

science classroom, the metacognitive strategy embedded in inquiry learning model, the effectiveness, and the factors affecting to the using of learning model.

1) **The problems in science classroom**

As problems related to classroom activities was students' lacking science process skills. It demonstrated that students' lack those process skills might related to learning activities and finally students could not acquire science knowledge. Furthermore, the problem of lacking science laboratory equipment in this survey might affect creating an activity of learning in science classroom; therefore, students had less chance to do the experiments. Moreover, Boonklurb (2000) reported that lacking of science equipment was a limitation of teaching/learning science in Thailand and the study of Colangelo et al (2009) suggested that school should support the lab material for science learning. A study of Kruea-In & Thongperm (2013) stated that insufficiency of laboratory equipment was a significant obstacle in the integration of science process skills into teaching. Therefore, students' achievement became low. Moreover, several reports showed that science process skills have positive correlation with science performance and achievement (Ong Saw Lan. 2006; Aydogdu. 2007; Feyzioglu, 2009; Oloyede, 2012; Volkan, Dilber, & Yasemin, 2012; Chaurasia, 2015) however some studies showed low positive correlation between the science process skills and achievement in science among high school students (Raj & Devi, 2014). Consequently, lacking of science process skills might affect to their achievement.

2) **The metacognitive strategy embedded in inquiry learning model**

The learning model was infused between inquiry based learning approach and metacognitive theory in terms of the regulation of cognition—planning (P), monitoring (M) evaluating (E). The learning model consisted of five phases namely; phase 1: Engagement-P-M-E, phase 2: Exploration-P-M-E, phase 3: Explanation-P-M-E, phase 4: Elaboration-P-M-E, and phase 5: Evaluation. Those features were focused on identifying the goal and then making a plan before doing tasks/ learning activities. Students then used the plan as a checklist to monitor their learning on-line procedures they also had opportunities to collaborate in planning/ doing tasks and share their ideas through the discussions in order to compare and make decision to fulfill their ideas in any phase of learning. Beyond it

enhanced students realized and open-mindedness from other perspectives. Finally, students attained the goals; five features of inquiry. Its detail in each phase of this learning model reflected what familiar with previous studies and why could enhance students' science process skills, science competencies, and self-efficacy. The details were as following;

Refer to the theoretical framework of this study in Chapter 2, the effectiveness of the using learning model was evaluated through students' science process skills, science competencies, and self-efficacy in science. The learning model could enhance students' performance as following;

The metacognitive strategy embedded in inquiry learning model consisted of 5Einquiry learning therefore, the goal in each phase of learning model is based on five essential features included 1) engagement-P-M-E phase, students finally reached the main question to explore based on their interesting in the short activities. They had to change that main question into the testable question. This is similar to Bybee et al (2006) stated that engage in a new concept through the use of short activities to promote students' curiosity and expose students' prior knowledge. Students propose the questions that they want to know and then make the question to be narrowed and sharpened (NRC. 2000; Barrow. 2006) which can be testable. However, as the sub-cycle steps of plan (P)-monitoring (M)-evaluating (E) of the learning model might lead students formulate the testable question by asking themselves before presenting and checking their ideas via whole class discussion. It is consistent with Kramarski & Mevarech (2003) suggested that students could ask themselves by comprehension question, strategy questions, and connection questions for completing the plan. Refer to students giving opinion in the informal interview, it was showed that students understand how to formulate the testable question; they can identify the component of testable question and describe how to formulate the testable question. Moreover, students stated that 'testable question' is new word for them and they can apply to science project subject however this study had found some students needed help. Therefore, it is important point to remind science teacher to make students clearly about testable question as it is the first step to explore/design the experiment, and could enhance student' ability on science competencies2; evaluate and design scientific enquiry. This is

similar to NRC (2000) stated that teacher plays a significant role in guiding the identification of questions. 2) exploration-P-M-E phase, students finally give priority on evidence. Set the testable question as a goal to find out the answers. Identify the needed evidence/data. Propose the ways to get those needed evidence/data based on students' experience by everyday language. Discussion and complete all plans in order to get the evidences before doing the experiment/explore. Students transfer experiment plan from every language into science terminology; hypothesis, variables, and defining operationally variable. Continue check the consistent among plan, goal, and procedure while doing experiment/investigation/task via checklist. Discuss about the results/data; comparing and inferring. Evaluate the evidence and all the results, inferring evidence/data, mistake.

This is similar to Bybee et al (2006) stated that learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation. The evidence is subject to questioning (NRC. 2000). While students make a plan before doing the experiment, the comprehension question can encourage students to reflect on a problem before solving it. Strategy questions can encourage students to think about what strategy might be appropriate for given task and provide a reason or rationale for that strategy choice (Kramarski; & Mevarech. 2003: 286 -287). Explicit prompt in the form of checklist with entries for planning, monitoring, and evaluating which also help students get more systemic and strategic during problem solving (Schraw. 1998). It could be said that planning and monitoring by checklist could encourage students to think about the strategies used in the process of learning and get more systemic while doing the experiments because students' opinions from the informal interview reflected that planning help them to understand what they learn, what they have to do, and why they have to do those procedures. They almost reflected that the planning in ISNs notebook is helpful to follow and check the procedures. They had more chances to monitor the process via discussion and especially with the clear plan and goal that would enhance students understand both the concept and process they learned. It showed students have more concern about the experiment process. In addition, students stated that have clearly plan before doing the experiment is new experience for them. However, using everyday language to plan the experiment process and then transfer

to science terminology makes students feel easy. In other hand, this point should be more consider as students finally have to do the test in formal language and involve science terminology students might face difficulties or feel not familiar with science terminology if the using learning model is not long time enough; same as this phenomena. In explanation-P-M-E phase and elaborate-P-M-E also had steps of planning-monitoring-evaluating. Provide students opportunities to demonstrate their conceptual understanding, process skills, or behaviors (Bybee et al. 2006). Students formulate explanations from evidence to address scientifically oriented questions, communicating and justifying proposed explanation (NRC. 2000). After discussion about the results students could use the plan and writing template of explanation to help them while formulate the explanation by themselves, students also monitor their ideas via discussion and fulfill the explanation. However, based on class observation, the gap was students' background affect to this step to make decision and fulfill own explanation. Moreover, based on informal interview had found that to explain by writing was a problem of some students which might affect to the test (paper-pencil test).

Thus, it demonstrated that this 5Es inquiry with regulation of cognition could make students concerned what they were doing in each step and more understood about process and product of learning activity which was positive to the research objectives. However, students also reflected that the classroom context with not annoying would more effectively use this learning model. In addition, the using of this learning was enhancing students to plan before doing any task with clearly goal, to find the ways to accomplish and to make a checklist then. They could realize the continually doing since beginning to success the task which influenced to their perceiving in capabilities and got higher level of self-efficacy.

However, to evaluate the learning model developed was required by the effectiveness of learning model on students' science process skills, students' science competencies and students' self-efficacy in science and its results of effectiveness was not attain all research objectives. It might because of the other factors affecting which are discussed.

3) **The effectiveness of metacognitive strategy embedded in inquiry learning model**

3.1 **Students' science process skills**

The post-test was not statistically significantly higher than pretest at 0.05 level. The finding was quite unusual due to the students complete the post-test only 15-20 minutes and the test was done in the last period of long testing whole Friday day which was different from pre-test that was done in the first period of the day and students completed it almost one hour. This study was consistent with the study of Seetee (2016) that students finished the science process skills test in short time was mentioned as the factor affecting to the development of eleventh grade students' science process skills. However, to attain the hypotheses, four factors were considered as factors affecting to enhance science process skills are as follows:

3.1.1 **Time limitation**: There were thirteen process skills to be enhanced in this study leaded students had not much doing the exercise/activities to learn in each skill explicitly in the class which was consistent with the study of Ong Saw Lan (2006) stated that experiment abilities needed to be practiced over a period of time. In addition, it had consistent with the previous studies that time constraint was mentioned as an obstacle for secondary school teacher (Kruea-In & Thongperm. 2014) and time limitation was a concern factor to succeed the implementation (Lati et al. 2012; Jeenthong et al. 2014).

3.1.2 **Students' experience and background knowledge**: This factor referred to students had experienced in daily life and their prior knowledge which were required to be a basic factor in order to propose and complete experiment designing via verbal casual (everyday language) at planning step and then adjust those propose into science process; less experience became an obstacle to make and propose a plan. It revealed that students who were sophisticate even their pretest score was low but they could propose the procedure of experiment however needed more time to transfer from everyday language into scientific terminology. This finding had consistent with previous research studies had mentioned about students' prior knowledge and cognitive abilities had affecting to the promoting of science process skills (Yvonne Beaumont & Walt. 2001: 142; Kruea-In & Thongperm. 2014; Jeenthong et al. 2014) especially was asserted that good

students' performance on integrated science process was depended on their experience with and domain-specific practice activities on the skills in prior task (Germann et al. 1996 cited in Yvonne Beaumont & Walt. 2001).

3.1.3 Assistance: Students who participated in the evaluating stage often needed help while learning, especially at planning stage such as to set the goal to find the answer and transferred the casual plan into science terminology. It was consistency with the study of Mei (2007) and Nelson (2004) had indicated that scaffolding was a key to help students acquired science process skills due to scaffolding guided students being able to learn new or complex skills and was required to read more in order to accomplish the research independently. However, Mei (2007) had suggested that balancing between providing students supported and allowed them to be independent learner was that considered by teacher. Thus, students' prior knowledge in this study was not high and slow learners, it might affect to students had less opportunities of own independently doing or they still needed scaffolding.

3.1.4 Attention: It was a factor affecting which was noticed from observation, informal interview was mentioned that their friends made noise, and the result revealed that students who pay attention had the posttest score higher than pretest which was consistent with the study of Krue-In & Thongperm (2014) stated that students' interesting was an factor affecting to the promoting of science process skills.

3.2 Students' science competencies

The posttest was statistically significantly higher than pre-test at 0.05 level. In addition, the post-test score was higher than pretest and statistic had found significant difference between pre-test and post-test in terms of interpret data and evidence scientifically. According to three science competencies in this study was referred to 'Science literacy' in PISA 2015 framework (OECD. 2016: 19). According to the statistic showed significantly might because of this learning model was based on inquiry learning which given students had frequently done in designing experiment in which they had to identify the needed evidences firstly in the planning step. Moreover, any planning in each phase of the learning model had to determine the goal and propose the ways to explore the

answer. These processes made students interpret more data or evidences which were consistent with the National Science Standards (1996), Paul Elliott (2010: online) and Lalia Halim (2015) had stated that science literacy could be achieved by emphasizing inquiry teaching and learning especially Hofstein et al (2004) had suggested inquiry-type laboratory work included identifying questions, forming hypothesis, designing and conducting scientific investigations, and formulating scientific explanations were important to develop science literacy however National Science Standards (1996) suggested that to achieve science literacy was taken time.

Nevertheless, in terms of design scientific enquiry and explain phenomena scientifically post-test showed not statistically significantly higher than pre-test at 0.05 level. Consequently, six factors might be considered in order to attain overall science competencies:

3.2.1 Students' experience and background knowledge: To achieve all three science competencies (science literacy 2015) were required both knowledge of concept and knowledge of the common procedure and practices associated with scientific enquiry and how to enable the advanced science (OECD. 2016: 18). In this study, the test was given on a subject that affects everyone's daily life, the atmosphere, weather and climate change that was required students to consider the effect in person/ local/ global level. It was required mastery skills and concept. But students in this study mostly needed helps therefore; students' experience and background knowledge might affect to accomplish those competencies. This finding had consistent with Seetee (2016) that students had low background in basic concept or underlying chemistry concept affected to hardly develop students' acid-base conceptual understanding.

Moreover, the metacognitive strategy embedded in inquiry learning model aimed students set the goal and planned at planning stage of 4E. It was revealed, especially at the exploration phase, that students that were less experienced could not to propose the ways to get the answer or data/resources or the evidence from the experiment. The researcher had noticed that students who were low achievers but had much experience could identify the goal and propose the ways. boys were better than girls, and high achievers could identify the goal and propose the ways with fluent casual dialogue. Thus,

students had experienced with encountering problems and practiced in thinking/ planning before making decision in daily life would be fostered to develop science competencies especially design scientific enquiry.

3.2.2 Students' science process skills: referred to the correlation between science process skills and science competencies of this study showed having strongly correlation (r = 0.704) (Evans. 1996). It could be indicated that students who had mastery on science process skills enabled them to achieve on science competencies and vice versa. Based on students' pretest and posttest on science process skills were not high therefore, it affected to students' science competencies. It used to be suggested by Krue-In & Thongperm (2014) that barely bound of science process skills in the classroom leaded students placed at low level of achievement both on national measurement (O-NET) and international measurement (TIMSS and PISA Measurement).

3.2.3 Students' readiness: to achieve science competencies, students had to apply both process skills and scientific knowledge related phenomena/ situations to explain reasonable based on evidence in the given data. In other hand, it needed both to learn science effectively and practice science (Yore; Bisanz;& Hand. 2003) whereas students' background knowledge was not high, most of them were slow learners and due to seventh grade students (12-13 years old) was a beginning period of formal-operational stage based on Piaget' s theory of cognitive development which suggested that children at 12-15-year-old can think abstractly and more complexly and become reasonable and good at problem solving thinking person when they grow up (IPST. 2013: 10). Students probably were inadequate to handle on science competencies. In other word, students' readiness was a factor affecting to develop science competencies. Students' readiness was stated by Yvonne Beaumont & Walt. (2001) that eighth grade students' poor performance on the skills of identifying variable and formulating hypotheses because the likelihood that students have never learned those skills and that students' levels of cognitive development is inadequate to handle with two skills. Furthermore, it was consistent with Rohaida & Kamariah (2005) who studied about web-based instructional material to acquire process skills and they suggested that students' readiness affect to students' acquisition basic and integrated science process skills due to fifth grade students have difficulties in handling the final level

of all the three simulate activities, they are unable to solve problem related to manipulation of multiple variables which is integrated in web-based program thus they choose to solve the problem by manipulating one at a time instead. This demonstrated that students are not cognitively ready to meet the demands of the instructional material. But, integrated science process skills were more appropriate at the high school levels and in higher education levels. The basic skills were the prerequisites for integrated skills (Akinbobola andAolabi, 2010: 33; Beaumont-Walters and Soyibo, 2001: 133 cited in Seetee. 2016: 249)

3.2.4 Language ability: researcher had found in Elaboration phase that many students finished reading the article but they could not mention what needed data/knowledge that had to know in order to get the answer. Researcher had to repeat reading and asked students to point out the important matter in each step, gave them more questions related the main idea then they could interpret those situations. Referred to the science competencies test was given information in paragraphs that might affect to students who were weakly reading comprehension to set the goal in order to explore the answer or to recall the scientific concept related those given information. Moreover, informal interview was reflected that student had faced difficulties in writing, it had found that some students wrote sentences not priority including they gave the answer not response to the question. Virginia Kearton (online) asserted that read, write, speak, debate and actively listening are the significant challenge for those who inexperienced in science. Therefore, it had to be more considered to on students' ability in language in order to accomplish on science competencies. Referred to scientifically literate person must be able to read, write and talk the language of science appropriately comfortably and effectively (Hodson. 2009: 241 cited in Virginia Kearton: online). Literacy in science was about the using of language in inquiry and the construction of meaning (Yore; Bisanz;& Hand. 2003; Paul Elliott. 2010: online). Thus, language ability was considered as a factor because students faced difficulties with reading and writing and this factor were also stated by Hodson (2009).

3.2.5 Familiarity with test format: According to science competencies test in this study was quite different from the previous science test that students had experienced with; they experienced with multiple choice and given short answer in science

test which was focused on content. This test was given real situation/ information/ articles and required students to use both process skills and to formulate explanation based on evidence in the given data with scientific reasoning. Students might not be familiar with this test format. It could be assumed by those short answer students response was based on the concept they had learned but was not in the given prompt. Additionally, most of subjects in the school evaluated students' achievement by the multiple choices test and sometimes in short answer test format. It was rare to ever see0 a writing test format. That might have lead to students lacking in writing or priority thinking. The study of Germann et al (1996) cited in Yvonne Beaumont-Walters & Kola Soyibo (2001) had considered that the effect of other subjects lacking of communication skills to express explicitly in writing as a factor affecting to TISPS-written performance test. However, an assessment method was reported that might affect to students' performance (Ruiz-Primo & Shavelson. 1996). It concurred to this study had found that students could explain when they were sought for step by step instead of writing in sentences.

3.2.6 **Students' belief and open-mindedness**: belief referred to student's belief which was shaped by social or their previous experience and could be expressed via their opinions to something. Their belief might inhibit students' learning when they encountered with various data to make decision. Due to they still believe on previous experiences. It was much tied and leaded students did not open mindedness to judge the phenomena/situations based on data/information. For example, students mostly still believed that only one factor; piece of metal leaded the people died from hit of lightning. Even though there were many factors induced the lightning, the possibility and intense level of lightning with percentage and sequence by descending were shown in that article/given prompt. However, in some items student just identified the evidence without given the reason completely. It was concurred with Srithep et al (2017) who had reported the study of seventy-two tenth grade science stream students' scientific explanation by asking ten open-ended questions about energy flow in different ecosystems to explore students' using evidence from the given data to support their explanation and connecting with scientific reasoning. The finding revealed that 69.4% of students make an accurate and complete claim, half of them can identify the evidence but 82 % of students do not provide the

reasoning to indicate the connection between their claim and evidence in order to make the complete scientific explanation. Students almost use their previous experiences or opinions to support their claims without using the evidence given in the prompt. These reflected that students' belief was an obstacle to challenge students' scientifically explanation development. Moreover, it was revealed that discussion in monitoring sub-phase could not effectively improve students' explanation as they already satisfied with their answer as it was already a partial correctly. It had found a few students made fulfilled writing from whole classroom discussion. Incomplete explanation had found in ISNs notebook and not many students used previous teacher's feedback or the scaffolding template of explanation to monitor their writing. It indicated an importance of scientific minds especially in terms of open-mindedness to improve students' explanation effectively. As a result, students were hardly changed and achieved in science competencies test which emphasized students to use the skills to identify evidences were given in the test and explain reasonable.

3.3 Students' self-efficacy in science

The posttest was statistical significantly higher than pretest at .05 level. Using this learning model, leaded students could realize the continually doing since beginning (planning) to success task and make monitoring during the processes which influenced to their perceiving in capabilities and got higher level of self-efficacy. That was consistent with Britner & Pajares (2006)had stated that hand-on activity leads students have mastery experience and improving their self-efficacy level. However, it had no correlation between science competencies and self-efficacy in science; Spearman's rho was .004 on posttest which was consistent with the report of PISA 2015 that at the country means there was weakly predictable students' motivation which had found in the report of PISA 2006 and especially in PISA 2015 had found students' average self-efficacy in science is not associated with a country's mean science performance (correlation: -0.2) especially some of the highest-performing countries; Japan and Viet Nam, the students in both countries reported lowest level of self-efficacy in science meanwhile among low-performing countries, had found great variation in students' self-efficacy (OECD. 2007; OECD. 2016: 140).

Moreover, Thai students still have higher level of self-efficacy than the OECD mean score average but lower mean score than the OECD in term of science literacy achievement. Even students had monitored and evaluated their abilities (self-evaluation and self-regulation) many times during the study but it could not change to be predicable for students' achievement. It was not consistent with the study of Motlagh et al (2011) found that self-regulation had high affecting to improve level of self-efficacy. It might because of the difference individual reference frame since the descriptive statistic showed students who got lower mean score of science competencies had lower mean score of self-efficacy in pretest but it found students who got lower mean score of science competencies had higher mean score of self-efficacy in posttest. However, the previous study showed positive correlation between science achievement and self-efficacy in science and also suggested that students' self-efficacy is important because it has correlated with achievement and if students have low level of self-efficacy, it could be help raise students' self-efficacy level through vicarious learning, metacognitive prompting, self-regulated learning, and goal setting.

4) The factors affecting to the using of learning model

Due to the effectiveness of metacognitive strategy embedded in inquiry learning model was not positive with all hypotheses. Finally, it could be consider the factors affecting in order to acquire more effectively learning model. That factors might were as following:

4.1 Students' background: It referred to students' experience and ability. According to the learning model in plan sub-phase related to set goal and make a plan. It needed students' experience/abilities in daily life that they had encountered to set the goal, identified what the needed data to be the evidence of making decision or exploration, and proposed the way to acquire the evidences. Due to students proposed via casual verbal based on their experiences and connected to science terminology and equipment later. However, boy was better than girl and high achiever could propose fluency. In addition, experience/prior knowledge was required when students made inferring data in experiments or phenomena scientifically when monitoring via discussion.

4.2 **Students' belief and open mindedness:** According to the learning model in monitoring sub-phase related to sharing and checking the plan or the explanation students had written. This phase was expected to make students shared their ideas via verbal and opened mind to correct perfectly explanation own including feedback from teacher to adjust in next learning activities. Based on observation and ISNs notebook, had found that not much students had done like the expectation. Unfortunately, they were already satisfied their ideas as it had a partial correctly. The metacognitive strategy embedded in inquiry learning model would be used more effectively if the students were not stuck with their previous belief and opened mind to the data they have presently.

4.3 **Classroom discipline:** According to the learning model enhances students had to complete plan before doing every step of 4E; engagement-P-M-E, exploration-P-M-E, explanation-P-M-E, and elaboration-P-M-E. It needed concentration on the plan. Some part of interview reflected that classroom discipline affected to learn by the metacognitive strategy embedded in inquiry learning model effectively. They liked the using of this learning model due to know how to formulate the testable question, understand whole processes before doing the experiment, know what the needed evidence to confirm their hypothesis. Consequently, it demonstrated that this learning model could solve the problem of students concern what they do while doing the experiment according to addressing in stage 1; preparation stage of this study. However students reflected that the concentration was required as a factor affecting while they were making plan and learning.

4.4 **Not complete learning phase in the classroom:** According to the time as the plan was not enough to finish all learning activities in the class leaded some activities were assigned to the students as homework. It might affect to students less monitoring and understanding.

4.5 **Time :** According to the timing was only eighteen hours which were less than IPST curriculum leaded since lesson plan 6 leads researcher gave some groups to present their ideas or measure by group working and moved to another step of learning activities. It was quite quickly for some students and might affect to some students lacking/ less practice in those topics. It needed longer time to improve all skills.

Limitations

1. Time limitation: time in evaluating phase less than the plan and had to request from other subjects leaded students were load learning in some day.

2. Students' attention in post-test as they completed the test only 15-20 minutes which was less than pre-test. The post-test was on the last period of long whole day of school examination week.

Recommendations

1) Recommendation for Policy

From the findings of this study, researcher would like the policy makers consider to;

1.1) To consider more integrating the integrated science process skills to lower secondary school students such as integrate in science contents since seventh grade due to the survey had found that lower school students had a level of science process skills decreasing by grade level (see APPENDIX E) and this study showed that students' science process skills had high correlation with science competencies (science literacy) ($r = 0.704$). Students were probably practiced many integrated skills before 15-year-old which they had to be assessed by PISA measurement including it would be promoted competencies before they encounter in daily life in the future.

1.2) The school should promote teachers in all subjects to construct a part of writing test in the test which probably make students sequence their ideas in communication as this study had found that students lacked in writing communication which affect to learning science.

2) Recommendation for Teacher

2.1) The teacher may use this learning model based on the considering factor affecting or use some techniques in the metacognitive strategy embedded in inquiry learning to help students having more concern when doing the experiment such as consider to use the ISNs notebook.

2.2) It needs time to complete all science process skills especially integrated science process skills for seventh grade students because their basic science process skills had found weakly in some skills teacher may fulfill students' basic science process skills and try to infuse the integrate integrated science process skills in the lesson plan step by step in long period time such as an academic year. The ISNs notebook with students' design experiment based on their experience is recommended as the students in this study showed that they can do it and had reflected via informal interview that they knew what they do and they liked it as they got more understanding on experiment procedures but not getting high score in the test; science terminology might be a new thing for them. Therefore, teacher has to consider this point and find more effectively techniques to make students are familiar with.

3) Recommendation for further research

3.1) To study factors affecting to the using of this learning model on developing students' science process skills, science competencies, and the correlation between self-efficacy and performance.

3.2) According to students' communication especially in writing was a factor affecting to this study. Moreover, Students reflected that they had faced difficulties when writing in order to reflect their thought. The further research may study students' language abilities and communication in learning science.

3.3) Since this study employ only 18 hours, therefore the further the learning model found from this research should be spent much more time in order to see the improvement of both science process skills and science competencies.

3.4) The learning model found from this research may be conducted with difference such as to study students' progression.

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APPENDIX

APPENDIX A

Lists of the experts

The Lists of experts who evaluate the learning model and research instruments

1. Associate Professor Dr. Chatree Faikhamta

Faculty of Education, Kasetsart University

2. Associate Professor Dr. Poonsuk U-dom

Faculty of Education, Taksin University

3. Mr. Wiroj Luewkongsathaporn

PISA Thailand, Institute for the Promotion of Teaching Science and Technology

4. Acting Sub Lt. Dr. Manat Boonprakorb

Behavioral Science Research Institute, Srinakharinwirot University

5. Assistant Professor Dr. Theerapong Saengpradit

Faculty of Science, Srinakharinwirot University

6. Assistant Professor Dr. Patcharee Rompayom Wichaidit

Faculty of Science and Technology, Thepsatri Rajabhat University

7. Assistant Professor Dr. Pattamaporn Pimthong

Faculty of Education, Kasetsart University

8. Assistant Professor Dr. Chaninan Pruekpramool

Faculty of Science, Srinakharinwirot University

9. Associate Professor Dr. Somsan Wong-Unoi

Faculty of Education, Srinakharinwirot University

10. Dr. Numtip Ongardwanich

Faculty of Education, Naresuan University

11. Dr. Parinda Limpanont Promrat

Faculty of Education, Chulalongkorn University

12. Associate Professor Dr. Prasart Nuengchalerm

Faculty of Education, Mahasarakham University

The lists of experts who participate as the investigator triangulation

1. Dr.Khuanruethai Thiangchanthathip

Srinagarindra the Princess Mother School, Phayao Province

2. Dr. Chuanpit Kanaphat

Nachareon School, Ubonratchathani Province

APPENDIX B

The results of evaluation of the learning model, lesson plans, and research instruments

B.1 The results of evaluation of the learning model

B.2 The results of evaluation of the lesson plans

B.3 The results of evaluation of science process skills test

B.4 The results of evaluation of science competencies test

B.5 The results of evaluation of self-efficacy in science test

B.1 The results of evaluation of the learning model

TABLE B.1.1 The results of evaluation on index of consistency (IOC) on the reflection of infusing of inquiry learning and regulation of cognition (part 1)

List of Evaluation	E1	E2	E3	IOC	Interpretation
1.The metacognition strategy embedded in learning inquiry model has the important features that reflects the infusing of inquiry learning and regulation of cognition	1.00	1.00	0.00	0.67	consistency
2.The metacognition strategy embedded in learning inquiry model has the phase or learning processes that reflects the infusing of inquiry learning and regulation of cognition	1.00	1.00	1.00	1.00	consistency
3.The metacognition strategy embedded in learning inquiry model has important features that could develop students' science process skills	1.00	0.00	1.00	0.67	consistency
4.The metacognition strategy embedded in learning inquiry model has the phase or learning processes that could enhance students' science process skills	1.00	1.00	1.00	1.00	consistency
5.The metacognition strategy embedded in learning inquiry model has important features that could enhance students' science competencies	0.00	1.00	1.00	0.67	consistency

TABLE B.1.1 (continued)

List of Evaluation	E1	E2	E3	IOC	Interpretation
6.The metacognition strategy embedded in learning inquiry model has the phase or learning processes that could enhance students' science competencies	0.00	1.00	1.00	0.67	consistency
7.The metacognition strategy embedded in learning inquiry model has important features that could adjust students' self-efficacy in science	0.00	1.00	1.00	0.67	consistency
8.The metacognition strategy embedded in learning inquiry model has phase or learning processes that could adjust students' self-efficacy in science	0.00	1.00	1.00	0.67	consistency
9.The metacognition strategy embedded in learning inquiry model has phase and continue clearly	1.00	1.00	0.00	0.67	consistency

* E1, E2, E3: The experts

TABLE B.1.2 The results of evaluation on index of consistency (IOC) on appropriateness of implementation in the classroom (part 2)

List of Evaluation	E1	E2	E3	IOC	Interpretation
1. The purposes and the roles of teacher and student in engagement-P-M-E is appropriate to adopt	1.00	1.00	1.00	1.00	consistency
2. The purposes and the roles of teacher and student in exploration-P-M-E is appropriate to adopt	1.00	0.33	0.67	0.67	consistency
3. The purposes and the roles of teacher and student in explanation-P-M-E is appropriate to adopt	1.00	1.00	1.00	1.00	consistency
4. The purposes and the roles of teacher and student in elaboration-P-M-E is appropriate to adopt	1.00	1.00	1.00	1.00	consistency
5. The purposes and the roles of teacher and student in evaluation phase is appropriate to adopt	1.00	1.00	0.67	0.89	consistency

* E1, E2, E3: The Experts

B.2 The results of evaluation of the lesson plans

The first drafts of lesson plans are evaluated and verified in term of appropriateness by two experts in the field of science education and one in field of education. The summarized results of appropriateness of all lesson plans are shown in table 3. The criteria of appropriateness lesson plan evaluation are shown below;

The appropriateness level	Scoring
Excellence	5
Good	4
Fair	3
Poor	2
Fail	1

The data is calculated as mean score for summary the level of appropriateness. The acceptance mean score of appropriateness is higher than 3.50 (Cojorn. 2011). Therefore, all first draft lesson plans are acceptance.

TABLE B.2 The summarized results of appropriateness of all lesson plans evaluation

List of Evaluation	Mean score of appropriateness level (n = 3)								
	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9
1 The standard/ indicator/ objective of learning were defined to have all the learning behaviors in terms of affective, process, and perceiving science self-efficacy	3.67	4.33	4.33	4.00	4.33	4.33	4.33	4.67	4.67
2 Had consistency between standard learning/ indicator/ content and learning activities	4.00	4.67	4.67	4.33	4.33	4.33	4.00	4.00	4.33

TABLE B.2 (continued)

List of Evaluation	Mean score of appropriateness level (n = 3)								
	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9
3 Learning activities was consistent with learning objectives	4.33	4.33	4.33	4.33	4.33	4.33	3.67	3.67	4.00
4 Learning activities in regulation of cognition (planning-monitoring-evaluating) had consistency with the goal of engagement phase	4.33	4.67	4.67	4.33	4.67	4.67	4.33	5.00	4.67
5 Learning activities in regulation of cognition (planning-monitoring-evaluating) had consistency with the goal of exploration phase	4.67	4.67	4.67	4.67	5.00	5.00	3.67	4.67	4.33
6 Learning activities in regulation of cognition (planning-monitoring-evaluating) had consistency with the goal of explanation phase	4.67	4.67	4.67	5.00	5.00	5.00	4.00	5.00	4.67

TABLE B.2 (continued)

List of Evaluation	Mean score of appropriateness level (n = 3)								
	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9
7 Learning activities in regulation of cognition (planning-monitoring-evaluating) had consistency with the goal of elaboration phase	4.67	4.67	4.67	4.33	4.67	5.00	4.33	4.33	4.67
8 Learning activities in regulation of cognition (planning-monitoring-evaluating) had consistency with the goal of evaluate phase	4.67	4.33	4.67	4.67	5.00	5.00	3.67	4.33	4.67
9 The evaluation method had consistency with learning objectives	3.33	3.67	3.67	3.33	4.00	4.00	4.00	4.00	4.33
10 Instructional materials and learning resources have consistency with learning objectives	4.67	4.67	4.67	4.67	4.33	4.33	5.00	5.00	5.00
Mean score	4.30	4.47	4.50	4.37	4.57	4.60	4.10	4.47	4.53
S.D.	0.48	0.32	0.32	0.46	0.35	0.38	0.42	0.48	0.28
Interpretation	Good	Good	Good	Good	Good	Good	Good	Good	Good

*LP: Lesson plan

The experts give comments and suggestions as follow;

Lesson Plan 1

-The learning objectives are not measured completely.

-Should use more constant words in writing, using too small letter in terms of pictures descriptions.

Lesson Plan 2

-The learning objectives are not measured completely.

Lesson Plan 3

-The learning objectives are not measured completely.

-Learning activities in each phase is interesting but in evaluation phase miss to measure some objectives.

-Time is probably not enough; it would be adjusted again after pilot study.

Lesson Plan 4

-The objectives are not consistent with indicators; need to add more objectives.

-The objective is not clear, especially in terms of process aspect. It affects to measurement not clearly.

Lesson Plan 5

-none-

Lesson Plan 6

-By general, learning activities are interesting. Metacognitive strategy is also interesting but not sure for the timing. Adjust the measurement form of all lesson plans. As it is not clear enough; it should be drawn in the table which is determined with clear criteria.

Lesson Plan 7

- It has discussion part in learning activities but no have in learning objective. In order to make consistent between objective and indicator, it should be added the objective in terms of discussion about tropical storm and added it to measure in evaluation phase.

-To determine many objectives which are too much expectation in behavior, in real classroom the classroom climate and outcome would be not succeeded.

-Learning activities in exploration and elaboration phases should be created more interesting. The researcher tries to focus on metacognitive regulation too much as a result the activities are not interesting.

-The questions to measure are general; just asking for apply. It could not be shown in terms of student behavior.

Lesson Plan 8

-Missed some indicators to measure.

-The measurement criteria are not clear.

-Good learning activities that make students get more interpreted in weather forecast but not completely in terms of discussion on weather affecting to living and environment. Therefore, add this topic into both indicator and objective of the lesson plan.

-Learning objectives are not covered by learning activities especially, process (p) aspect.

- The questions to measure are general; just asking for apply. It could not be shown in terms of student behavior.

Lesson Plan 9

-An advantage is using both real data and graph which lead students know real situation. However, should be more focused on discussion in order to get concept according the objectives setting.

-Lots of document for searching therefore should be added an active reading activities to help students.

B.3 The results of evaluation of science process skills test

Item	IOC	p	r	Item	IOC	p	r
1	0.67	0.60	0.56	21	0.73	0.70	0.44
2	0.87	0.30	0.26	22	0.67	0.49	0.44
3	0.80	0.68	0.59	23	0.87	0.59	0.41
4	0.80	0.34	0.37	24	0.87	0.44	0.22
5	1.00	0.75	0.20	25	0.93	0.53	0.48
6	0.87	0.62	0.30	26	0.80	0.44	0.26
7	1.00	0.76	0.44	27	1.00	0.71	0.56
8	1.00	0.80	0.37	28	1.00	0.34	0.33
9	0.93	0.31	0.37	29	0.87	0.53	0.41
10	0.67	0.37	0.30	30	0.93	0.80	0.41
11	0.73	0.58	0.67	31	1.00	0.58	0.56
12	1.00	0.46	0.44	32	1.00	0.53	0.56
13	1.00	0.66	0.41	33	1.00	0.46	0.44
14	1.00	0.40	0.20	34	0.40	0.55	0.67
15	0.87	0.73	0.44	35	0.67	0.52	0.44
16	0.87	0.80	0.52	36	0.87	0.62	0.59
17	0.67	0.80	0.48	37	1.00	0.48	0.59
18	0.87	0.74	0.41	38	0.73	0.27	0.37
19	0.93	0.60	0.56	39	0.73	0.29	0.33
20	0.87	0.74	0.44	40	0.93	0.37	0.22

Reliability (KR-20) is 0.83.

B.4 The results of evaluation of science competencies test

TABLE B.4.1 Multiple choice

Item	IOC	p	r
1	1.00	0.89	0.30
2	1.00	0.66	0.85
3	0.89	0.57	0.91

Reliability (KR-20) is 0.42

TABLE B.4.2 Complex choice

Item	IOC	p	r
1	0.67	0.76	0.29
2	1.00	0.63	0.20
3	1.00	0.35	0.28
4	0.67	0.34	0.22
5	0.67	0.65	0.30
6	0.56	0.76	0.29
7	1.00	0.55	0.27
8	1.00	0.67	0.23
9	1.00	0.69	0.31

Reliability (KR-20) is 0.53.

TABLE B.4.3 Writing

Item	IOC	p	r
1	1.00	0.59	0.39
2	1.00	0.21	0.27
3	0.89	0.26	0.25
4	0.89	0.24	0.32
5	0.67	0.46	0.23
6	1.00	0.34	0.27
7	0.89	0.34	0.33
8	0.89	0.41	0.65
9	0.89	0.38	0.60
10	1.00	0.35	0.27

Reliability (α) is 0.53

B.5 The results of evaluation of self-efficacy in science test

TABLE B.5 The results of evaluation of self-efficacy in science test

Item	Evaluation by the experts				
	E1	E 2	E 3	IOC	Interpretation
1. ฉันมั่นใจว่าสามารถอธิบายปรากฏการณ์ต่าง ๆ ที่เกิดขึ้นในชั้นบรรยากาศแต	1.00	1.00	1.00	1.00	consistency
2. ฉันไม่สามารถอธิบายสาเหตุที่ทำให้เกิดภาวะโลกร้อนได้	1.00	1.00	1.00	1.00	consistency
3. ฉันมั่นใจว่าสามารถคำนวณโจทย์ปัญหาเกี่ยวกับความดันอากาศ ความชื้นอากาศได้ถูกต้อง	1.00	1.00	1.00	1.00	consistency
4. ฉันมั่นใจว่าสามารถอธิบายสาเหตุที่ทำให้อุณหภูมิในช่วงเช้า กลางวัน และเย็นแตกต่างกันได้	1.00	1.00	1.00	1.00	consistency
5. ฉันมั่นใจว่าสามารถบอกได้ว่าการใช้รถที่มีเครื่องยนต์ขนาดเล็กและใหญ่ ส่งผลต่อการเกิดปรากฏการณ์เรือนกระจกแตกต่างกันอย่างไร	1.00	1.00	1.00	1.00	consistency
6. ฉันมั่นใจว่าสามารถเชื่อมโยงข้อมูลจากหลายแหล่งเพื่ออธิบายปรากฏการณ์ทางลมฟ้าอากาศได้ถูกต้อง	1.00	1.00	1.00	1.00	consistency
7. ฉันมั่นใจว่าสามารถอธิบายปรากฏการณ์รูโหว่โอโซนฝนกรด ต่อสิ่งมีชีวิตและสิ่งแวดล้อมได้	1.00	1.00	1.00	1.00	consistency
8. ฉันมั่นใจว่าสามารถอธิบายหลักการเกิดลมได้ถูกต้อง	1.00	1.00	1.00	1.00	consistency
9. เมื่อฉันเห็นเมฆปรากฏ ฉันมั่นใจว่าสามารถบอกได้ว่าเป็นเมฆก่อให้เกิดฝน	1.00	1.00	1.00	1.00	consistency
10. ฉันมั่นใจว่าสามารถอธิบายถึงสาเหตุที่ทำให้เขตบางขุนเทียนหรือพื้นที่เรียบฝั่งทะเล มีน้ำทะเลล้ำเข้ามาผืนดินมากกว่าอดีต	0.67	1.00	1.00	0.89	consistency
11. ฉันจะล้มเลิกการหาคำตอบ เมื่อพบว่าต้องใช้กระบวนการที่ยากหลายขั้นตอนในการหาคำตอบนั้น	1.00	1.00	1.00	1.00	consistency

TABLE B.5 (continued)

Item	Evaluation by the experts				
	E 1	E 2	E 3	IOC	Interpretation
12. ฉันมั่นใจว่าสามารถออกแบบการทดลองใด ๆ ที่เกี่ยวกับปรากฏการณ์ลมฟ้าอากาศ (เช่น ผลกระทบจากฝนกรด) ได้	1.00	1.00	1.00	1.00	consistency
13. ฉันมั่นใจว่าสามารถใช้ความรู้ทางวิทยาศาสตร์ที่เรียนมา เสนอแนวทางแก้ไขที่หลากหลายเพื่อแก้ปัญหาเกี่ยวกับลมฟ้าอากาศและสิ่งแวดล้อม	1.00	1.00	1.00	1.00	consistency
14. เมื่อพบปัญหาวิทยาศาสตร์ใด ๆ เกี่ยวกับบรรยากาศลมฟ้าอากาศ ฉันมั่นใจว่าสามารถสร้างสมมติฐานที่นำไปสู่การทดลองตรวจสอบหาคำตอบได้	1.00	1.00	1.00	1.00	consistency
15. ไม่ว่าปัญหาใด ๆ ฉันมั่นใจว่าสามารถใช้ทักษะกระบวนการทางวิทยาศาสตร์ที่เรียนมา สืบเสาะหาคำตอบปัญหาให้สำเร็จได้	1.00	1.00	1.00	1.00	consistency
16. เมื่อต้องออกแบบการทดลองด้วยตนเอง ฉันมั่นใจว่าสามารถบอกขั้นตอนและเหตุผลที่ต้องจัดกระทำในขั้นตอนนั้น ๆ ได้	1.00	1.00	1.00	1.00	consistency
17. เมื่อต้องทำการทดลองเปรียบเทียบความสามารถในการดูดรังสีความร้อนของวัสดุ ต่าง ๆ บนโลก ฉันมั่นใจว่าสามารถระบุอุปกรณ์เครื่องมือที่ต้องใช้ทั้งหมดได้ถูกต้อง	0.67	1.00	1.00	0.89	consistency
18. ฉันไม่มั่นใจเกี่ยวกับวิธีการใช้เครื่องมืออุปกรณ์การทดลองในห้องปฏิบัติการ	0.67	1.00	1.00	0.89	consistency
19. เมื่อต้องทำการทดลองใด ๆ เช่น ฝนกรดและผลกระทบของฝนกรด การดูดและคายความร้อนของสาร ฉันมั่นใจว่าสามารถระบุข้อมูลที่ต้องเก็บรวบรวม เพื่อนำมาใช้เป็นหลักฐานยืนยันในการสรุปผล	1.00	1.00	1.00	1.00	consistency
20. ฉันมั่นใจว่าสามารถใช้ความมุ่งมั่นพยายามทำงานวิทยาศาสตร์ใด ๆ ให้สำเร็จได้	1.00	1.00	1.00	1.00	consistency
21. ถ้ามีการทำการทดลองเกี่ยวกับลมฟ้าอากาศทั้งแบบยาก-ง่ายหลากหลายให้เลือก ฉันมั่นใจว่าจะเลือกทำการทดลองที่ยากท้าทายความสามารถตนเอง	1.00	1.00	1.00	1.00	consistency

TABLE B.5 (continued)

Item	Evaluation by the experts				
	E 1	E 2	E 3	IOC	Interpretation
22. เมื่อมีนโยบายปรับผังเมืองใหม่ จัดให้พื้นที่ส่วนใหญ่ปลูกต้นไม้สร้างสวนสาธารณะแทนการสร้างห้างสรรพสินค้า ฉันจะไม่สนับสนุนนโยบายนี้	0.33	1.00	1.00	0.77	consistency
23. ฉันมั่นใจว่าสามารถประเมินสาเหตุ/ระบุความเป็นไปได้เกี่ยวกับเหตุการณ์ทางลมฟ้าอากาศ เช่น ฟ้าผ่า ได้จากข้อมูลที่ปรากฏในข่าว	1.00	1.00	1.00	1.00	consistency
24. ฉันมั่นใจว่าสามารถใช้ความรู้เรื่องการเกิดลม ในการระบุตำแหน่งที่เหมาะสมในการติดตั้งประตูหรือหน้าต่างเพื่อให้ลมพัดผ่านห้องได้สะดวก	0.67	1.00	1.00	0.89	consistency
25. เมื่อฟังข่าวพยากรณ์อากาศที่มีข้อมูลหย่อมความกดอากาศสูงต่ำแล้ว ฉันมั่นใจว่าสามารถบอกเกี่ยวกับอุณหภูมิในพื้นที่ดังกล่าวได้	0.67	1.00	1.00	0.89	consistency
26. ฉันสามารถทำความเข้าใจข่าวหรือบทความเกี่ยวกับลมฟ้าอากาศที่ปรากฏในสื่อ ต่าง ๆ ได้	1.00	1.00	1.00	1.00	consistency
27. ฉันรู้วิธีการเตรียมตัวและปฏิบัติตัว เมื่อร่างกายต้องอยู่ในที่ ๆ มีความดันอากาศเปลี่ยนไปจากเดิม เช่น เทือกเขา บนเครื่องบิน หรือหุบเขา	1.00	1.00	1.00	1.00	consistency
28. ฉันมั่นใจว่าสามารถนำความรู้เรื่อง การสะท้อนและดูดกลืนรังสีจากดวงอาทิตย์ของวัสดุ เป็นแนวทางในการตัดสินใจเลือกทาสีบ้านเพื่อลดความร้อนของบ้านได้	0.67	1.00	1.00	0.89	consistency
29. เมื่อฉันฟังข่าวเกี่ยวกับลมมรสุมตะวันออกเฉียงเหนือและมรสุมตะวันตกเฉียงใต้พัดผ่านบริเวณที่ฉันอาศัยอยู่ (กรุงเทพ) ฉันมั่นใจว่าสามารถคาดการณ์สภาพอากาศที่จะเกิดขึ้นได้	1.00	1.00	1.00	1.00	consistency
30. ฉันมั่นใจว่าสามารถใช้ทักษะการสังเกตและความรู้ที่เรียนแล้วทำความเข้าใจ กราฟ แผนภาพ หรือแหล่งข้อมูลอื่นเกี่ยวกับลมฟ้าอากาศหรือสิ่งที่พบเห็นในชีวิตประจำวันอื่น ๆ ได้	1.00	1.00	1.00	1.00	consistency
31. จากข้อโต้แย้งว่า “โรงไฟฟ้านิวเคลียร์ในไทยเหมาะสมหรือไม่” ฉันจะสนับสนุนให้มีโรงไฟฟ้านิวเคลียร์ เนื่องจากจะช่วยลดภาวะ	1.00	1.00	1.00	1.00	consistency

TABLE B.5 (continued)

Item	Evaluation by the experts				
	E 1	E 2	E 3	IOC	Interpretation
โลกร้อนได้					
32. ฉันมั่นใจว่าสามารถระบุข้อมูลหลักฐานที่ใช้ยืนยันว่า รถยนต์ที่มากขึ้นส่งผลกระทบต่อการเกิดภาวะโลกร้อนที่มากขึ้นได้	0.33	1.00	1.00	0.77	consistency
33. ฉันมั่นใจว่าสามารถใช้ความรู้ที่เรียนมา เลือกช่วงเวลาที่จะไปเที่ยวทะเลฝั่งอันดามันได้โดยไม่เจอลมมรสุมฝนตกได้	1.00	1.00	1.00	1.00	consistency
34. เมื่อต้องโต้แย้งหรือสนับสนุนประเด็นเกี่ยวกับลมฟ้าอากาศของโลก ฉันมั่นใจว่าสามารถเลือกใช้ข้อมูลหลักฐานมามาสนับสนุนหรือโต้แย้งได้	1.00	1.00	1.00	1.00	consistency
35. เมื่อเพื่อนนำเสนองานจบ ฉันสามารถร่วมอภิปรายและเสนอแนะในประเด็นที่เพื่อนนำเสนอได้	1.00	1.00	1.00	1.00	consistency
36. ฉันสามารถพูดนำเสนอประเด็นต่าง ๆ ตรงตามเป้าหมายที่ฉันวางแผนไว้ ได้ครบประเด็น	0.67	1.00	1.00	0.89	consistency
37. เมื่อมีข้อมูลกราฟนำเสนอเกี่ยวกับลมฟ้าอากาศ (แปรปรวน) ในปัจจุบัน ฉันมั่นใจว่าสามารถอธิบายข้อมูลในกราฟนั้นให้เพื่อนเข้าใจได้	1.00	1.00	1.00	1.00	consistency
38. ฉันมั่นใจว่าสามารถเขียนสื่อความบอกแนวคิดเกี่ยวกับบรรยากาศ ลมฟ้าอากาศที่เรียนแล้วได้ตรงตามที่ฉันคิดนำเสนอ	1.00	1.00	1.00	1.00	consistency
39. ฉันมั่นใจว่าสามารถเลือกใช้วิธีการนำเสนอข้อมูลที่เหมาะสมกับเนื้อหาและเข้าใจง่ายได้	1.00	1.00	1.00	1.00	consistency
40. เมื่อต้องอภิปรายหรือแสดงความคิดเห็นต่องาน ฉันมั่นใจว่าสามารถนำเสนอได้โดยมีหลักฐานและเหตุผลประกอบชัดเจน	1.00	1.00	1.00	1.00	consistency
41. ฉันรู้สึกไม่สบายใจ หากต้องพูดหรืออธิบายสิ่งที่เกี่ยวข้องกับบรรยากาศ ลมฟ้าอากาศที่เรียนมาแล้วให้เพื่อนฟัง	1.00	1.00	1.00	1.00	consistency

Reliability ($\propto$) is 0.91

APPENDIX C

Lesson plan

แผนการจัดการเรียนรู้ที่ 2

เรื่อง ผลของรังสีจากดวงอาทิตย์ต่อบรรยากาศ และอุณหภูมิอากาศ จำนวน 2 ชั่วโมง

หน่วยการเรียนรู้ที่ 1 บรรยากาศ จำนวน 12 ชั่วโมง

รายวิชา วิทยาศาสตร์พื้นฐาน 2 ชั้นมัธยมศึกษาปีที่ 1

สาระการเรียนรู้/มาตรฐานการเรียนรู้

สาระที่ 6 กระบวนการเปลี่ยนแปลงของโลก

มาตรฐาน ว 6.1 เข้าใจกระบวนการต่างๆที่เกิดขึ้นบนผิวโลกและภายในโลก ความสัมพันธ์ของกระบวนการต่างๆที่มีผลต่อการเปลี่ยนแปลงภูมิอากาศ ภูมิประเทศ และสัณฐานของโลก มีกระบวนการสืบเสาะหาความรู้และจิตวิทยาศาสตร์ สื่อสารสิ่งที่เรียนรู้และนำความรู้ไปใช้ประโยชน์

ตัวชี้วัด ม. ว 6.1 ม. 1/1 ทดลองและอธิบายความสัมพันธ์ระหว่างอุณหภูมิ ความชื้น และความกดอากาศ ที่มีผลต่อปรากฏการณ์ทางลมฟ้าอากาศ

สาระที่ 8 ธรรมชาติของวิทยาศาสตร์และเทคโนโลยี

มาตรฐาน ว 8.1 ใช้กระบวนการทางวิทยาศาสตร์และจิตวิทยาศาสตร์ในการสืบเสาะหาความรู้ การแก้ปัญหา รู้ว่าปรากฏการณ์ทางธรรมชาติที่เกิดขึ้นส่วนใหญ่มีรูปแบบที่แน่นอน สามารถอธิบายและตรวจสอบได้ ภายใต้ข้อมูลและเครื่องมือที่มีอยู่ในช่วงเวลานั้นๆ เข้าใจว่าวิทยาศาสตร์ เทคโนโลยี สังคม และสิ่งแวดล้อม มีความเกี่ยวข้องสัมพันธ์กัน

ตัวชี้วัด ม. ว 8.1 ม. 1/1 ตั้งคำถามที่กำหนดประเด็นหรือตัวแปรที่สำคัญในการสำรวจตรวจสอบหรือศึกษาค้นคว้าเรื่องที่สนใจได้อย่างครอบคลุมและเชื่อถือได้

ตัวชี้วัด ม. ว 8.1 ม. 1/2 สร้างสมมติฐานที่สามารถตรวจสอบได้ และวางแผนการสำรวจตรวจสอบหลาย ๆ วิธี

ตัวชี้วัด ม. ว 8.1 ม. 1/4 รวบรวมข้อมูล จัดกระทำข้อมูลเชิงปริมาณและเชิงคุณภาพ

ตัวชี้วัด ม. ว 8.1 ม. 1/6 วิเคราะห์และประเมินความสอดคล้องของประจักษ์พยานกับข้อสรุป ทั้งที่สนับสนุนหรือขัดแย้งกับสมมติฐานและความผิดปกติของข้อมูลจากการสำรวจตรวจสอบ

สาระสำคัญ

อุณหภูมิ ความชื้น และความกดอากาศ มีผลต่อปรากฏการณ์ทางลมฟ้าอากาศ อุณหภูมิของอากาศบนโลกในแต่ละที่มีอุณหภูมิไม่เท่ากัน เนื่องจากโลกกลม จึงทำให้พื้นผิวโลกได้รับพลังงานจาก

ดวงอาทิตย์ได้ไม่เท่ากัน นอกจากนี้ แต่ละพื้นที่ของพื้นผิวโลกจะสะท้อนและดูดกลืนพลังงานจากดวงอาทิตย์ได้แตกต่างกัน จึงทำให้อุณหภูมิอากาศแต่ละพื้นที่ไม่เท่ากัน

จุดประสงค์การเรียนรู้ เมื่อเรียนจบหัวข้อนี้แล้ว นักเรียนควรจะสามารถ

ด้านเนื้อหา

1. อ่าน วิเคราะห์ และแปลความข้อมูลจากแผนภาพการสะท้อนและดูดกลืนรังสีจากดวงอาทิตย์ที่แผ่มายังโลก ในหนังสือเรียน
2. ทดลอง รวบรวมข้อมูล และอธิบายปริมาณการดูดกลืนรังสีจากดวงอาทิตย์และการคายความร้อนของสิ่งต่างๆบนพื้นผิวโลกที่มีลักษณะต่างกัน
3. อภิปรายและอธิบายผลของรังสีจากดวงอาทิตย์ที่มีต่ออุณหภูมิอากาศที่พื้นผิวโลก

ด้านทักษะกระบวนการ

1. ออกแบบการทดลอง เพื่อทดสอบการดูดกลืนรังสีความร้อนจากดวงอาทิตย์ และคายพลังงานความร้อนของดิน น้ำ และทราย
2. ระบุตัวแปรที่เกี่ยวข้องกับการทดลองได้
3. เขียนกราฟแสดงความสัมพันธ์ระหว่างอุณหภูมิกับเวลาของการดูดกลืนรังสีความร้อนจากดวงอาทิตย์ และคายพลังงานความร้อนของดิน น้ำ และทราย

ด้านการรับรู้ความสามารถทางวิทยาศาสตร์

1. ระบุความสามารถของตนผ่านการประเมินตนเอง การอภิปราย และคำชมเชยแนะนำจากเพื่อนและครู

กิจกรรมการเรียนรู้

1.ขั้นสร้างความสนใจ *(Engage: planning* – monitoring** - evaluating***)*

จากกรณีมีการแชร์ภาพ ร.ต.อ.กัมปนาท จันทร์ศรีบุตร นายตำรวจน้ำดีที่ไม่ย่อท้อ อดทนทำหน้าที่นายตำรวจเกียรติยศ ถวายความปลอดภัยในภารกิจซ้อมรื้วขบวนพระบรมราชอิสริยยศ เมื่อวันที่ 21 ต.ค.ที่ผ่านมา แม้เขาจะมีบาดแผลที่หัวเข่าจากการสัมผัสกับความร้อนของถนนเป็นเวลานาน แต่ ร.ต.อ.กัมปนาท ก็ไม่ขอถอนตัวจากภารกิจใดทั้งสิ้นในการถวายความปลอดภัยรื้วขบวนพระบรมราชอิสริยยศ รื้วขบวนที่ 2 และ 6 และขอปฏิบัติหน้าที่อย่างเต็มที่ที่สุดเท่าที่ชีวิตข้าราชการตำรวจจะกระทำได้ ให้สมกับคำว่า "ตำรวจพระราชา"

ที่มา: http://www.newtv.co.th/news/6946

1.1 ครูแสดงภาพตำรวจที่นั่งพับเพียบที่พื้นถนนแล้วมีแผลพุพองที่หัวเข่า แล้วให้นักเรียนตั้งคำถามที่เกี่ยวข้องจากภาพ

- ทำไมหัวเข่าจึงพุพอง ได้รับความร้อนมาจากไหน ?" (พื้นถนนร้อน)
- พื้นถนนได้รับความร้อนมาจากไหน (ดวงอาทิตย์)
- แล้วความร้อนสะสมอยู่ในโลกได้อย่างไร ?" (สิ่งต่าง ๆ บนโลก เช่น พื้นผิวโลก ดิน น้ำ ตึกอาคาร แก๊สต่าง ๆ ในอากาศ ดูดความร้อนจากดวงอาทิตย์เก็บสะสมเอาไว้)
- ทราบได้อย่างไร (เวลาเดินเท้าเปล่าบนพื้นปูนกลางแจ้ง แล้วรู้สึกร้อนที่ฝ่าเท้า แต่ถ้าเดินช่วงเวลาที่ไม่มีแสงแดดกลับไม่รู้สึกร้อน)
- แล้วช่วงมีแสงเหมือนกัน ถ้าให้เลือกนั่งได้ จะเลือกนั่งบริเวณไหน? ทำไม?
- นักเรียนกล่าวถึง ประเด็นความสามารถในการดูดกลืนความร้อนจากดวงอาทิตย์ของพื้นผิวดูดกลืนได้เหมือนหรือต่างกัน? จะทราบได้อย่างไร? จงตั้งคำถามที่สามารถตรวจสอบได้"

วางแผน *planning*	P1-ครูแสดงข้อความ... *ตั้งคำถามที่สามารถตรวจสอบได้ ว่าพื้นผิวแต่ละชนิดดูดกลืนความร้อนจากดวงอาทิตย์ต่างกันจริงหรือไม่?* ผ่านจอโปรเจคเตอร์ P2-ครูยกตัวอย่าง คำถามที่ตรวจสอบได้ และคำถามที่ตรวจสอบไม่ได้ เป็นแนวทางให้นักเรียน (กรณีคาบแรกของการเรียน: เรียนรู้คำถามที่ตรวจสอบได้ โดยคละคำถาม แล้วให้นักเรียนจัดหมวดหมู่คำถาม แล้วเฉลย จากนั้นให้นักเรียนพิจารณาคำถามที่จำแนกกลุ่มออกแล้วนั้น ลงข้อสรุปว่าคำถามที่ตรวจสอบได้ มีอะไรที่เหมือนกัน องค์ประกอบสำคัญคืออะไร) P3-จากประเด็นในขั้นกระตุ้นความสนใจ นักเรียนแต่ละกลุ่มย่อยร่วมกันตั้งคำถามที่ตรวจสอบได้ (Testable question) แล้วเขียนในส่วนวางแผนและคาดเดา ด้านซ้ายของใบงานที่ 1 เรื่อง รังสีจากดวงอาทิตย์ ซึ่งมีรูปแบบเป็น Interactive student notebook (ISNs) โดยเตือนตัวเองด้วย 4 คำถาม ได้แก่ อะไรที่รู้แล้ว อะไรที่ไม่รู้ อะไรที่ต้องรู้เพิ่ม จะทำอย่างไร -อะไรที่รู้แล้ว (รู้ว่าจะทดสอบอะไรหรือยัง? --- > ตัวแปรต้นในคำถามที่ตรวจสอบได้) -อะไรที่ยังไม่รู้ (รู้ว่าต้องการดูอะไรหรือยัง? --- > ตัวแปรตามในคำถามที่ตรวจสอบได้)

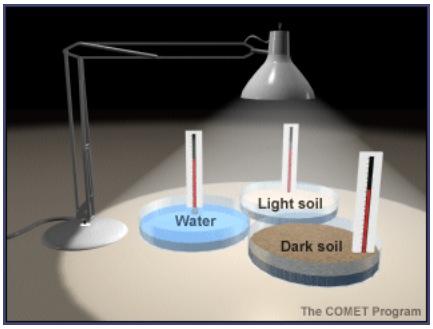
	-อะไรที่ต้องรู้เพิ่ม (มีอะไรที่ต้องรู้หรือระมัดระวังในการตั้งคำถามที่ตรวจสอบได้) -จะทำอย่างไร (จะประกอบเป็นคำถามอย่างไรจึงจะนำไปสู่การทดลองได้ / จะตรวจสอบว่าเป็นคำถามที่ตรวจสอบได้ (Testable question) อย่างไร ใครช่วยตรวจสอบได้)
ตรวจสอบ *monitoring*	M1-นักเรียนตรวจสอบคำถามที่ตรวจสอบได้ (Testable question) ที่เขียนผ่านการตั้งคำถามถามตนเองและสมาชิกในกลุ่ม/ห้อง การรวบรวมและเปรียบเทียบข้อมูลจากการนำเสนอของเพื่อนแต่ละกลุ่ม M2-ครูแสดงรายการตรวจสอบ (Checklist) การตั้งคำถามที่ตรวจสอบได้และเขียนคำถามที่นักเรียนเสนอบนกระดาน เพื่อให้นักเรียนเห็นมุมมองที่หลากหลาย M3-นักเรียนร่วมกันบอกจุดร่วม/ลักษณะสำคัญของคำถามที่ตรวจสอบได้ แล้วลองเชื่อมโยงหลักในการตั้งคำถามที่ตรวจสอบได้กับข้อคำถามที่กลุ่มตั้งขึ้น เพื่อดูว่าสอดคล้องหรือไม่ ต้องแก้ไขอะไร
ประเมิน *evaluating*	E1-นักเรียนได้ประเมินตนเอง ผ่านการอภิปรายในขั้นตรวจสอบแล้วเปรียบเทียบ-พิจารณาตัดสินจนได้คำถามที่ตรวจสอบได้ครบถ้วนตามหลักเกณฑ์ ตามเป้าหมายที่ต้องการ แล้วเขียนในส่วนการทดลอง ด้านขวาของใบงานข้อที่ 2 ในใบงานที่ 1 เรื่องรังสีจากดวงอาทิตย์ ซึ่งอาจได้คำถาม ดังนี้ *“พื้นผิวแต่ละชนิดมีความสามารถในการดูดกลืนความร้อนได้แตกต่างกันหรือไม่”*

2. ขั้นสำรวจและค้นหา** (Explore : planning* – monitoring** - evaluating)*

2.1 นักเรียนแต่ละกลุ่มทบทวนคำถามที่สร้างขึ้น *“พื้นผิวของสารแต่ละชนิดมีความสามารถในการดูดกลืนความร้อนได้แตกต่างกันหรือไม่”* แล้วเขียนลงในใบงานที่ 2 ซึ่งมีรูปแบบเป็น Interactive student notebook (ISNs)

2.2 นักเรียนอภิปรายร่วมกับครูเพื่อวางแผนคร่าว ๆ เกี่ยวกับการดำเนินการทดลองในแง่วิธีการ เครื่องมืออุปกรณ์ที่ต้องใช้ การวัด ระยะเวลาในการทดลอง การกำหนดและควบคุมตัวแปร และสิ่งที่จะได้จากการทดลอง รวมทั้งคาดเดาผลที่จะเกิดขึ้นจากการทดลอง

วางแผน *planning*	P1-ครูแสดงข้อความ... *หาหลักฐานที่บอกว่าพื้นผิวแต่ละชนิดดูดกลืนความร้อนได้แตกต่างกัน ?* ผ่านจอโปรเจคเตอร์หรือป้ายแสดงข้อความให้นักเรียนเห็นก่อนเริ่มคิดวางแผน/ระดมความคิด วางแผนเพื่อให้ได้คำตอบมา P2-นักเรียนแต่ละกลุ่มย่อยร่วมกันคิด วิธีการที่จะนำไปสู่การได้หลักฐานมาตอบคำถามที่ตั้งขึ้น "*พื้นผิวของสารแต่ละชนิดมีความสามารถในการดูดกลืนความร้อนได้แตกต่างกันหรือไม่*" โดยเตือนตัวเองด้วย 4 คำถามหลัก ได้แก่ -อะไรที่รู้แล้ว ------ > พื้นผิวชนิดต่าง ๆ -อะไรที่ไม่รู้ ------ > ความสามารถในการดูดกลืนความร้อน -อะไรที่ต้องรู้เพิ่ม จะทำอย่างไร ------ > เช่น จะใช้พื้นผิวอะไรมาทดสอบเปรียบเทียบบ้าง ใช้อะไรแทนความร้อนจากดวงอาทิตย์ -สมาชิกในกลุ่มเคยมีประสบการณ์เกี่ยวกับการดูดกลืนความร้อนไหม -จะวัดอะไรจากการทดลองนี้ ใช้เครื่องมือใดวัด -หลักฐานที่บ่งบอกว่าสารใดดูดกลืนความร้อนมาก-น้อย คืออะไร -จะใช้เวลาทดลองนานเท่าไหร่ ทำการวัดกี่ครั้ง -ต้องระมัดระวังเรื่องใดเป็นพิเศษ เพื่อให้การทดลองเปรียบเทียบน่าเชื่อถือ ไม่มีอคติ -ภาพการทดลองคร่าว ๆ เป็นอย่างไร แบ่งหน้าที่รับผิดชอบ -คาดเดาว่าผลการทดลองจะเป็นอย่างไร P3-นักเรียนเขียนการวางแผน ลงด้านซ้ายของในใบงานซึ่งเป็น Interactive student notebook (ISNs)
ตรวจสอบ *monitoring*	M1-นักเรียนตรวจสอบสิ่งที่คิดที่เขียนไปแล้วในใบงานด้านซ้ายและตรวจสอบผลการทดลองที่เกิดขึ้นว่ามีความเป็นไปได้หรือมีข้อมูลที่อาจคลาดเคลื่อนหรือผิดปกติหรือไม่ -หลักฐานที่ต้องการคืออะไร -ได้ข้อมูลหลักฐานตามต้องการหรือยัง -ตรวจสอบการจัดวางการทดลอง การอ่านค่าจากการวัด (ดังภาพด้านล่าง) -พบสิ่งที่ทำให้ข้อมูลคลาดเคลื่อนหรือไม่ เพราะเหตุใดจึงเป็นเช่นนั้น จะแก้ไขอย่างไร

	 ที่มา: https://www.ucar.edu/learn/1_1_2_5t.htm
ประเมิน *evaluating*	E1-นักเรียนประเมินว่าได้ข้อมูลตามที่วางแผนไว้ครบหรือไม่ โดยการพูดคุยกับเพื่อนในกลุ่มและเพื่อนต่างกลุ่ม พร้อมทั้งเปรียบเทียบแนวโน้มของข้อมูลกับเพื่อนต่างกลุ่ม อภิปราย พิจารณาตัดสินจนมั่นใจว่าหลักฐานที่ได้ตอบเป้าหมายที่ต้องการ E2-นักเรียนประเมินผลการดำเนินการทดลอง มีอะไรต้องแก้ไข มีอะไรที่อยากศึกษาต่อยอด แล้วเขียนในใบงานซึ่งเป็น Interactive student notebook (ISNs)

ขั้นอธิบายและลงข้อสรุป *(Explain : planning* – monitoring** - evaluating***)*

3.1 นักเรียนและครูร่วมกันอภิปรายและสรุปผลการทดลอง มีครูตั้งคำถามเพื่อนำไปสู่การลงข้อสรุป ดังนี้

- จากการทดลอง นักเรียนทราบว่าดินร่วน ทราย และน้ำมีการดูดกลืนความร้อนได้มากหรือน้อย สามารถสังเกตได้จากสิ่งใด? (อุณหภูมิที่เพิ่มขึ้นจากเดิม)
- การดูดกลืนความร้อนของสารทั้งสามชนิดเท่ากันหรือไม่ อย่างไร?

(ไม่เท่ากัน ทรายดูดกลืนความร้อนได้มากที่สุดเพราะมีอุณหภูมิต่างจากเดิมมากที่สุด) รองลงมาคือ ดิน ร่วน และน้ำดูดกลืนความร้อนได้น้อยที่สุด)

3.2 นักเรียนดำเนินการผ่านกระบวนการควบคุมตนเอง เพื่อสร้างคำอธิบายและลงข้อสรุป ตลอดจนวางแผนเขียนนำเสนอข้อมูลในรูปกราฟ

วางแผน *planning*	P1-นักเรียนวางแผนเขียนเรียบเรียงข้อสรุป โดยย้อนกลับไปดูที่วัตถุประสงค์/เป้าหมายของการทดลองนี้ เพื่อให้สามารถระบุหลักฐานประจักษ์พยานอ้างอิงชัดเจนประกอบการเขียนสรุปผล -เป้าหมาย

	-สิ่งที่ดำเนินการทดลอง -ผลลัพธ์/หลักฐานที่ได้ -ตีความจากหลักฐานที่พบ P2-ครูแสดงข้อความ... *หลักฐานที่บ่งบอกสารดูดกลืนความร้อนได้แตกต่างกัน* ? ผ่านจอโปรเจคเตอร์หรือป้ายแสดงข้อความให้นักเรียนเห็นก่อนเริ่มคิดวางแผน/ระดมความคิด เขียนเรียบเรียงข้อสรุป พร้อมชี้แนะการเขียนอธิบายคำตอบเป็นความเรียงออกมา ควรประกอบด้วยประเด็นต่อไปนี้ - เป้าหมายของข้อคำถามนี้ คืออะไร? - คำถามที่ตรวจสอบได้? - สิ่งที่ดำเนินการทดลอง? - ผลลัพธ์/หลักฐานที่ได้? - การตีความจากหลักฐานที่พบ?
ตรวจสอบ *monitoring*	M1-นักเรียนตรวจสอบสิ่งที่เขียนสรุป ผ่านการตั้งคำถามถามตนเองหรือทำเช็คลิสต์หรือเทียบกับสมาชิกในกลุ่ม และการนำเสนอของเพื่อนที่ถูกสุ่มให้นำเสนอ -การสรุปที่เขียนขึ้น มีความสอดคล้องกับเป้าหมายที่ตั้งไว้หรือไม่ -เติมข้อมูลในกราฟครบถ้วนแล้วหรือยัง
ประเมิน *evaluating*	E1-นักเรียนได้ประเมินตนเอง ผ่านการอภิปรายเพื่อน -เห็นด้วยกับสิ่งที่เพื่อนสรุปหรือไม่ อย่างไร -มีส่วนใด ประเด็นใดที่ต้องแก้ไข ปรับเปลี่ยน

3.3 หลังจากประเมินการเขียนอธิบาย นักเรียนควรได้สาระสำคัญจากการทดลอง และนำเสนอว่า.. *"หลอดไฟแผ่รังสีมาถึงภาชนะแต่ละใบเท่ากัน เนื่องจากวางอยู่บริเวณเดียวกัน แต่ในเวลาที่รับรังสีจากดวงอาทิตย์เท่ากันคือ 15 นาที พบว่า ดิน ทราย และน้ำดูดกลืนและเปลี่ยนรังสีดวงอาทิตย์เป็นพลังงานความร้อนได้แตกต่างกัน ซึ่งสังเกตได้จากอุณหภูมิที่เปลี่ยนไป กล่าวคือ ทรายมีอุณหภูมิเปลี่ยนไปมากที่สุด และน้ำมีอุณหภูมิเปลี่ยนไปน้อยที่สุด ดังนั้น เรียงลำดับความสามารถในการดูดกลืนรังสีจากดวงอาทิตย์ได้ ดังนี้ ทราย > ดินร่วน > น้ำ"*

3.4 ครูใช้คำถามเพิ่มเติม

-ถ้าตำรวจท่านนั้นต้องนั่งเช่นเดิม เพื่อไม่ให้ตำรวจคนนั้นได้รับความร้อนจากพื้นถนน นักเรียนจะช่วยแก้ไขด้วยวิธีการใด (ใช้วัตถุที่เป็นฉนวนความร้อนรองก่อนนั่ง/ ใส่กางเกงหนา ๆ)

-นักเรียนคิดว่าอุณหภูมิอากาศบริเวณที่ตำรวจนั่งกลางแจ้ง กับอุณหภูมิอากาศบริเวณริมถนนที่มีร่มเงาจากต้นไม้ มีอุณหภูมิอากาศเท่ากันหรือไม่ (ไม่เท่ากัน)

-นักเรียนคิดว่าการดูดกลืนความร้อนของสิ่งต่างๆที่กล่าวมา ส่งผลต่ออุณหภูมิของอากาศบริเวณรอบ ๆ หรือไม่ อย่างไร (น่าจะส่งผลต่ออุณหภูมิรอบ ๆ เพราะคายความร้อนให้บริเวณรอบ ๆ)

3.5 ครูตั้งข้อสังเกตจากภาพแอฟพลิเคชันบนโทรศัพท์มือถือ (Application) แสดงอุณหภูมิในหนึ่งวันว่า

- ทำไมอุณหภูมิในช่วงเย็นถึงค่อยๆลดลง แทนที่จะคงที่เท่าเดิมกับตอนที่มีรังสีจากดวงอาทิตย์ เพราะเหตุใดอุณหภูมิกลับค่อยๆลดลง (เพราะพื้นผิวโลกมีการคายความร้อนด้วย)

3.6 ครูอธิบายเพิ่มเติมว่า

“ดวงอาทิตย์แผ่รังสีมายังโลก รังสีบางส่วนจะมีการสะท้อนกลับสู่อวกาศ บางส่วนถูกดูดกลืนโดยแก๊สต่างๆในบรรยากาศ เมฆ และส่วนที่เหลือจะลงมาถึงบริเวณผิวโลก และบริเวณพื้นผิวโลก ได้แก่ ต้นไม้ สิ่งก่อสร้าง พื้นดิน พื้นน้ำ ภูเขา จะมีการดูดกลืนรังสีจากดวงอาทิตย์และมีการคายความร้อนให้กับพื้นผิวโลก”

3.7 นักเรียนอ่าน วิเคราะห์ และแปลความข้อมูลจากแผนภาพการสะท้อนและดูดกลืนรังสีจากดวงอาทิตย์ที่แผ่มายังโลก ในหนังสือเรียน ครูใช้คำถาม นักเรียนคิดว่าการคายความร้อนของสิ่งต่างๆที่กล่าวมา เหมือนหรือต่างกัน? (ต่างกัน)

จะทราบได้อย่างไร?

ขั้นขยายความรู้ *(Elaborate : planning* – monitoring** - evaluating***)*

4.1 นักเรียนดำเนินกิจกรรมขั้นนี้ ลงในใบงานที่ 2 การดูดและคายความร้อนจากดวงอาทิตย์ขอพื้นผบนโลกเพื่อสามารถออกแบบการทดลองได้ โดยประยุกต์ใช้กระบวนการสำรวจตรวจสอบที่ได้เรียนมาแล้วใน 3 ขั้นตอน เมื่อจบกิจกรรมขั้นนี้ นักเรียนต้องสามารถตั้งคำถามที่สำรวจตรวจสอบได้ ออกแบบการทดลองเพื่อได้หลักฐานเชิงประจักษ์ได้ อธิบายเกี่ยวกับหลักฐานที่ได้จากการทดลองได้ สื่อสารและตัดสินข้อมูลได้ ด้วยคำถาม 3 ข้อ *(โดยออกแบบและคาดการณ์ผลการทดลอง ไม่ได้ดำเนินการทดลองจริง ข้อ 1 และตอบคำถามด้วยการเรียบเรียงอธิบาย ข้อ 2)*

4.2 นักเรียนใช้หลักการ ต่อไปนี้ในการดำเนินการหาตอบของทั้ง 3 คำถาม

- วางแผน(อะไรรู้แล้ว อะไรที่ไม่รู้ อะไรที่ต้องรู้เพิ่ม จะทำอย่างไร)
- ตรวจสอบ
- ประเมินผล

ข้อ 1 การคายความร้อนของดินร่วน ทราย และน้ำ เหมือนหรือต่างกัน อย่างไร
ข้อ 2 พื้นที่ที่มีป่าและพื้นที่ที่ป่าไม้ถูกทำลาย ส่งผลให้บริเวณรอบ ๆ มีอุณหภูมิเหมือนหรือต่างกัน อย่างไร

วางแผน *planning*	P1-นักเรียนพิจารณาคำถาม แล้วตั้งคำถามที่ตรวจสอบได้ (Testable question) และวางแผนการทดลอง เพื่อให้สามารถระบุหลักฐานประจักษ์พยานอ้างอิงชัดเจนได้ P2-ครูแสดงข้อความ... *หลักฐานสำคัญที่ต้องใช้ในการตอบคำถามนี้?* ผ่านจอภาพหรือป้ายแสดงข้อความให้นักเรียนเห็นก่อนเริ่มคิดวางแผน/ระดมความคิด -นักเรียนเขียนวางแผนรายละเอียดขั้นตอนดำเนินการ โดยกำหนดประเด็น เหล่านี้ - เป้าหมายของข้อคำถามนี้ คืออะไร? - สิ่งที่ดำเนินการทดลอง? - ผลลัพธ์/หลักฐานที่ได้? - การตีความจากหลักฐานที่พบ? - มีสิ่งที่เป็นข้อจำกัดหรือไม่ จะแก้ไขอย่างไร?
ตรวจสอบ *monitoring*	M1-นักเรียนตรวจสอบสิ่งที่เขียน ผ่านการอภิปรายกลุ่มหรือทำการตรวจสอบรายการ (Checklist) จากที่วางแผนไว้ เพื่อให้ครบถ้วนและป้องกันการคลาดเคลื่อนของข้อมูล
ประเมิน *evaluating*	E1-นักเรียนเขียนการดำเนินการที่จะตอบคำถามข้อที่เลือกทำนั้น โดยในการเขียนต้องประกอบด้วย - เป้าหมายของข้อคำถามนี้ คืออะไร? - คำถามที่ตรวจสอบได้? - สิ่งที่ดำเนินการทดลอง? - ผลลัพธ์/หลักฐานที่ได้? - การตีความจากหลักฐานที่พบ? E2-ครูหรือเพื่อนต่างกลุ่มประเมินความถูกต้องในคำตอบที่เขียน เห็นด้วยกับสิ่งที่

	นักเรียนเขียนสรุปตอบหรือไม่ อย่างไร -มีส่วนใด ประเด็นใดที่ต้องแก้ไข ปรับเปลี่ยนเพิ่มเติม

เนื้อหาที่นักเรียนควรจะได้รับ/เรียนรู้ หลังจากทำใบงานที่ 3 ในส่วนของการออกแบบการทดลอง มีดังนี้

"เนื่องจากวางอยู่บริเวณเดียวกัน และใช้เวลาในการคายความร้อนเท่ากันคือ 15 นาที พบว่า ดิน ทราย และน้ำ คายความร้อนได้แตกต่างกัน ซึ่งสังเกตได้จากอุณหภูมิที่เปลี่ยนไป กล่าวคือ ทรายมีอุณหภูมิลดลงมากที่สุด และน้ำมีอุณหภูมิลดลงน้อยที่สุด ดังนั้น เรียงลำดับความสามารถในการคายความร้อนได้ ดังนี้ ทราย > ดินร่วน > น้ำ

ดังนั้น พื้นผิวโลกที่มีลักษณะแตกต่างกัน เช่น บริเวณที่มีแหล่งน้ำ มีต้นไม้ พื้นดิน พื้นทราย/บริเวณทะเลทรายแห้งแล้ง ก็จะมีการดูดกลืนเพื่อสะสมพลังงานความร้อนได้แตกต่างกัน ขณะเดียวกันการคายความร้อนออกมาก็เกิดได้ต่างกันด้วย จึงทำให้อุณหภูมิอากาศบริเวณเหนือพื้นผิวดังกล่าวในเวลากลางวันและกลางคืน ในแต่ละพื้นที่มีความแตกต่างกันด้วย"

ขั้นประเมินผล (Evaluate)

1. นักเรียนตรวจสอบความรู้ตนเองผ่านหัวข้อ "สรุปสาระสำคัญ วันนี้ได้เรียนรู้อะไร"
2. นักเรียนตอบคำถามว่า "ผลของรังสีจากดวงอาทิตย์ สามารถนำไปใช้ประโยชน์ มีความเกี่ยวข้องหรือมีผลกระทบในระดับบุคคล ชุมชน สังคม ประเทศ โลกอย่างไร?"

การประเมินผล

การตอบคำถาม / การร่วมทำกิจกรรม การทำใบงานต่าง ๆ การ สรุปสาระสำคัญ วันนี้ได้เรียนรู้อะไร การเขียนอนุทิน(Journal)

สิ่งที่ต้องการวัด	วิธีการ	เครื่องมือ	เกณฑ์การประเมิน
อ่าน วิเคราะห์ และแปลความข้อมูลจากแผนภาพการสะท้อนและดูดกลืนรังสีจากดวงอาทิตย์ที่แผ่มายังโลก ในหนังสือเรียน	สังเกต	ภาพใน Power point	ตีความกราฟได้
ทดลอง รวบรวมข้อมูล และอธิบาย	ตรวจจากใบงาน	แบบประเมินการ	ได้คะแนนร้อยละ

ปริมาณการดูดกลืนรังสีจากดวงอาทิตย์และการคายความร้อนของสิ่งต่าง ๆ บนพื้นผิวโลกที่มีลักษณะต่างกัน อภิปรายและอธิบายผลของรังสีจากดวงอาทิตย์ที่มีต่ออุณหภูมิอากาศที่พื้นผิวโลก	/การถามตอบ อธิบายแผนภาพ สังเกตจากการมีส่วนร่วม	ให้คะแนน	60 ขึ้นไป การสรุปสาระสำคัญ
สังเกตสิ่งที่กำหนดให้ แล้วระบุประเด็นสำคัญจากสิ่งที่สังเกตได้ ใช้ทักษะการรทดลอง ทักษะตีความหมายข้อมูล ทักษะการสื่อสารในการทำความเข้าใจข้อมูลและนำเสนอข้อมูล	การสังเกต /การถามตอบ อธิบายแผนภาพ	แบบสังเกต แบบสังเกต	ได้คะแนน 3 ใน 5 ได้คะแนน 3 ใน 5
ระบุระดับความสามารถทางวิทยาศาสตร์ของตนเอง จากการประเมินตนเอง การรับฟังคำชมเชยแนะนำจากเพื่อนและครู	การระบุความสามารถตนเองของนักเรียน	แบบประเมินตนเอง ความรู้ความเข้าใจ กิจกรรมการเรียนรู้	ดูความสอดคล้องโดยนำไปเทียบคะแนนการทำใบงานและการสังเกตจากครู

สื่อการเรียนรู้

1. Power point นำเสนอประกอบการทำกิจกรรม
2. อุปกรณ์การทำการทดลอง
3. ใบงานที่ 1 ผลของรังสีจากดวงอาทิตย์ (ISNs notebook)
4. ใบงานที่ 2 การดูดและคายความร้อนจากดวงอาทิตย์ของพื้นผิวบนโลก
5. ใบสรุปสาระสำคัญ วันนี้ได้เรียนรู้อะไร
6. หนังสือเรียนวิชาวิทยาศาสตร์พื้นฐาน 2

บันทึกผลหลังการจัดการเรียนรู้

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ปัญหาและอุปสรรค

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ข้อเสนอแนะและแนวทางแก้ไข

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ลงชื่อ .....

(.....)

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ชื่อ – สกุล ..... ชั้น ม.1/…… เลขที่.....

สรุปสาระสำคัญ วันนี้ได้เรียนรู้อะไร

ระบุเป้าหมายที่นักเรียนต้องการ	สิ่งที่เคยรู้แล้ว หรือ สิ่งที่คาดเดาผิด	สิ่งที่ได้เรียนรู้ใหม่ / รู้เพิ่มเติม
ขั้นการตั้งคำถามก่อนทดลอง ขั้นการหาหลักฐาน (ทำการทดลอง) ขั้นการอธิบาย (สรุปผลการทดลอง) ขั้นขยายความรู้ (ตอบคำถามใบงานที่ 2)		

✎**นักเรียนประเมินตนเอง ความรู้ความเข้าใจเกี่ยวกับผลของรังสีจากดวงอาทิตย์ต่อบรรยากาศ**

(คะแนนก่อนเรียนได้ ...../10 คะแนน คะแนนหลังเรียนได้ ...../10 คะแนน) เพราะ.....

.....

✎นักเรียนคิดว่า “ผลของรังสีจากดวงอาทิตย์ สามารถนำไปใช้ประโยชน์ มีความเกี่ยวข้องหรือมีผลกระทบในระดับบุคคล ชุมชน สังคม ประเทศ โลกอย่างไร?”

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เพื่อนประเมิน ความรู้ความเข้าใจจากใบงานและการร่วมกิจกรรมในห้อง (ได้ ...../10 คะแนน)

คำชมเชยหรือข้อแนะนำอื่น ๆ .....

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..... ลงชื่อ..... ผู้ประเมิน

✎**ครูประเมิน** ความรู้ความเข้าใจจากใบงานและการร่วมกิจกรรมในห้อง (ได้ ...../10 คะแนน)

คำชมเชยหรือข้อแนะนำอื่น ๆ .....

..... ลงชื่อ..... ผู้ประเมิน

ใบงานที่ 1 การทดลองเรื่อง รังสีจากดวงอาทิตย์

❶การวางแผนและคาดเดา (นักเรียนเติมคำตอบสั้นๆเป็นโน้ตย่อตามความเข้าใจเกี่ยวกับการดำเนินการทำการทดลองอย่างคร่าว ๆ)

1 เป้าหมายที่อยากรู้คืออะไร

2 ลองตั้งคำถามที่ตรวจสอบได้

3 คาดเดาผลการทดลองว่าเป็นอย่างไร

4 ต้องใช้อุปกรณ์อะไรบ้าง จะใช้พื้นผิวอะไรมาทดสอบเปรียบเทียบบ้าง

5 ใช้อะไรแทนความร้อนจากดวงอาทิตย์

6 ต้องการทราบ/อยากดู อะไรจากการทดลอง

7 หลักฐานที่ใช้ยืนยันว่ามีการดูดกลืนความร้อนคืออะไร

8 ทดลองเพียงอันเดียว หรือ ทดลองเปรียบเทียบกัน (วงกลมล้อมรอบ)

9 สิ่งใดที่ทำให้ต่างกัน

10 สิ่งใดที่ต้องทำให้เหมือนกัน ขณะทดลองแต่ละอัน

11 วัดอะไรจากการทดลองนี้

12 วัดออกมาเป็นตัวเลขได้หรือไม่?

13 ใช้เครื่องมืออะไรวัด?

14 จะใช้เวลาทดลองนานเท่าไหร่ ทำการวัดกี่ครั้ง

15 ต้องระมัดระวังเรื่องใดเป็นพิเศษ เพื่อให้การทดลองน่าเชื่อถือ ไม่มีอคติ

วาดภาพ แสดงขั้นตอนการทดลอง

ชื่อ-สกุล .....

ชั้น ม. 1/..... เลขที่..... กลุ่มที่.....

❷ก่อนทดลอง

วัตถุประสงค์[1] .....

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คำถามที่ตรวจสอบได้[2].....

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ความรู้เดิมหรือข้อมูลที่เกี่ยวข้อง

- ***อุณหภูมิ*** *คือ ระดับความร้อนที่ปรากฏในมวลสารต่างๆ สามารถบอกค่าได้เป็นตัวเลขที่แน่นอน โดยใช้เครื่องมือวัดชื่อ "เทอร์มอมิเตอร์"*
- ***อุณหภูมิที่เปลี่ยนไป*** *คือ อุณหภูมิสารหลังทดอง – อุณหภูมิสารก่อนทดลอง*
- ***ตัวแปรต้น*** *คือ สิ่งที่ต้องการศึกษา/ สิ่งที่ทำให้แตกต่าง*
- ***ตัวแปรตาม*** *คือ ผลที่เกิดขึ้นจากการทดลอง*
- ***ตัวแปรควบคุม*** *คือ สิ่งที่ต้องจัดกระทำให้เหมือนกันในการทดลอง*

สมมติฐาน[3].....

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ตัวแปรต้น[9].....

ตัวแปรตาม[6] .....

ตัวแปรควบคุม[10].....

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นิยามตัวแปรตาม[6 - > 11]

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การทดลอง

อุปกรณ์เครื่องมือที่ใช้ทดลอง.....

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ใบงานที่ 1 รังสีจากดวงอาทิตย์

4 วางแผนเพื่อเขียนอธิบาย/สรุป ผลการทดลองด้วยคำถาม 5 ข้อ

1 คำถามที่ตรวจสอบได้?

2 หลักฐานที่ต้องใช้ยืนยันคือ?

3 ผลการทดลองพบว่า?

4 จากหลักฐานที่ใช้และผลการทดลอง แสดงให้เห็นว่า?

5 มีข้อมูลเพิ่มเติมอื่น ๆ ที่เกี่ยวข้องกับผลการทดลอง?

6 เขียนสิ่งที่ได้เรียนรู้มากขึ้น จากการทำการทดลองนี้

7 นำผลการทดลองที่ค้นพบ ไปใช้ประโยชน์ในชีวิตได้หรือไม่ อย่างไร

8 สิ่งที่อยากรู้ / ข้อสงสัยเพิ่มเติม ที่อยากรู้คำตอบ

3 การทดลอง (ต่อ) ผลการทดลอง

สาร	อุณหภูมิที่อ่านได้ (°C)					ผลต่างอุณหภูมิสุดท้ายกับเริ่มต้น (°C)
	นาทีที่ 0	นาทีที่ 3	นาทีที่ 6	นาทีที่ 9	นาทีที่ 15	
ดิน						
ทราย						
น้ำ						

ทำเครื่องหมาย ✓ ตรวจเช็ค ที่ได้ทำแล้วหรือที่จำได้

☐ เป้าหมายที่ทดลองคืออะไร ☐ ใช้อะไรเป็นหลักฐานยืนยัน

☐ บันทึกครบหรือยัง ได้หลักฐานครบหรือยัง ☐ มีอะไรผิดพลาด..? เพราะอะไร ?

กราฟแสดงการดูดกลืนความร้อนจากหลอดไฟของดิน น้ำ และทราย ในเวลา 15 นาที

5 สรุปผลการทดลอง

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APPENDIX D

Example of research instruments

D.1 Science process skills test

D.2 Science competencies test

D.3 Self-efficacy in science test

(In Thai)

D.1 Science Process Skills

แบบวัดทักษะกระบวนการทางวิทยาศาสตร์

คำชี้แจงเกี่ยวกับแบบวัด

แบบวัดทักษะกระบวนการทางวิทยาศาสตร์นี้ เป็นส่วนหนึ่งของเครื่องมือวิจัยของปริญญานิพนธ์ เรื่อง “การพัฒนารูปแบบการเรียนรู้แบบสืบเสาะหาความรู้โดยกลวิธีทางอภิปัญญา เพื่อส่งเสริมสมรรถนะทางวิทยาศาสตร์ ทักษะกระบวนการทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1”

1. แบบวัดทักษะกระบวนการทางวิทยาศาสตร์ชุดนี้ มีจำนวน 40 ข้อ แบ่งเป็น
   -ทักษะกระบวนการทางวิทยาศาสตร์ขั้นพื้นฐาน จำนวน 26 ข้อ 26 คะแนน
   -ทักษะกระบวนการทางวิทยาศาสตร์ขั้นบูรณาการ จำนวน 14 ข้อ 14 คะแนน

2. ใช้เวลาทำแบบวัด 1 ชั่วโมง

3. แบบวัดทักษะกระบวนการทางวิทยาศาสตร์ เป็นแบบปรนัย 4 ตัวเลือก ให้นักเรียนทำเครื่องหมาย O ล้อมรอบ ข้อที่เห็นว่าถูกต้องที่สุดเพียงคำตอบเดียวลงในกระดาษคำตอบที่อยู่ส่วนท้ายของแบบวัด

4. การตอบแบบวัดทักษะกระบวนการทางวิทยาศาสตร์นี้ จะไม่มีผลเสียใด ๆ ต่อผลการเรียนของนักเรียนข้อมูลที่ได้จากแบบวัดนี้ จะใช้สำหรับการวิจัยครั้งนี้เท่านั้น

ขอขอบคุณนักเรียนทุกคนมา ณ ที่นี้ ที่เสียสละเวลาและให้ความร่วมมือในการตอบคำถามแบบวัดนี้เป็นอย่างดี

เบญญาภา ประชานันท์
(นางสาวเบญญาภา ประชานันท์)
นิสิตหลักสูตรการศึกษาดุษฎีบัณฑิต สาขาวิทยาศาสตรศึกษา
ศูนย์วิทยาศาสตรศึกษา คณะวิทยาศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ

Observing

ข้อ 1 การบันทึกผลการสังเกตในข้อใดต่อไปนี้ ใช้ประสาทสัมผัสหลายทางที่สุด

ก. กระเป๋าสีดำใบนั้น ทำจากหนังชั้นดี การันตีด้วยกลิ่นหนังแท้ ๆ

ข. แตงโมลูกนี้เคาะแล้วเสียงดังตึง ๆ จึงลองผ่าดู เนื้อแดงกรอบ รสหวานมาก

ค. ผลไม้ลูกนี้จับดูผิวสากมีตานูน ๆ มีกลิ่นหอมเนื้อด้านในมีสีเหลืองรสชาติหวาน

ง. ชายคนนั้นมีผิวสีแทน ผมยาวมีหนวดเครา เสียงทุ้ม ตอนเดินผ่านได้กลิ่นอาหารติดตัวด้วย

Classifying

นักเรียนคนที่	เพศ	สัญชาติ	ปีเกิด (ค.ศ.)	ส่วนสูง (cm)
1	ชาย	ไทย	2002	170
2	ชาย	จีน	2001	180
3	หญิง	จีน	2003	165
4	ชาย	ญี่ปุ่น	2001	175
5	หญิง	ไทย	2001	159

ข้อ 2 เกณฑ์ในการจำแนกข้อใด **<u>ไม่สามารถ</u>**ใช้แบ่งกลุ่มให้ได้มากกว่า 2 กลุ่ม ได้

ก. เพศ ข. สัญชาติ ค. ส่วนสูง ง. ปีเกิด

Measuring

ข้อ 3 ป้ายบอกทาง ระยะห่างของตึกแต่ละตึกในโรงเรียน ควรระบุด้วยหน่วยวัดใด

ก. ฟุต ข. เมตร ค. กิโลเมตร ง. เซนติเมตร

Using space/time relationship

ข้อ 4

<u>คำชี้แจง</u> ใช้ภาพแสดงพิกัดแผนที่นี้ ตอบคำถามข้อ 4

ให้พิจารณา ภาพแสดงพิกัดแผนที่ ขณะที่ผู้หญิงกำลังตามหาตัวโปเกม่อน จากภาพผู้หญิงคนนี้หันหน้าไปทางทิศใด

ก. ทิศเหนือ

ข. ทิศใต้

ค. ทิศตะวันออก

ง. ทิศตะวันตก

Using number

ข้อมูลแสดงอุณหภูมิอากาศ ณ เมืองต่าง ๆ ตามเวลาท้องถิ่นของแต่ละประเทศ เมื่อวันที่ 5 ธันวาคม 2559

ชื่อเมือง	อุณหภูมิอากาศ (°C)
กรุงเทพฯ	31
โตเกียว	16
มอสโค	-8
วอชิงตัน	4
เบอร์ลิน	-5
กัวลาลัมเปอร์	33

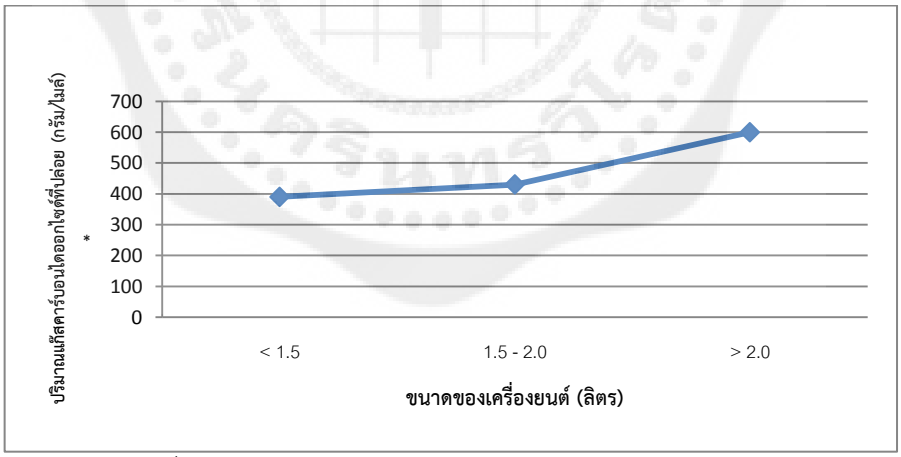
ที่มา: https://www.timeanddate.com/weather/

ข้อ 5 จากข้อมูลข้างต้น เมืองใดอากาศเย็นมากที่สุด

ก. กัวลาลัมเปอร์ ข. วอชิงตัน ค. เบอร์ลิน ง. มอสโค

Communicating

ข้อ 6 กราฟแสดงการปล่อยแก๊สคาร์บอนไดออกไซด์ของรถยนต์ขนาดต่าง ๆ



ที่มา: http://www.carbonindependent.org/sources_car.html

ข้อใดอธิบายความสัมพันธ์ของตัวแปรได้ถูกต้อง

ก. เครื่องยนต์ขนาดเล็กจึงทำให้ปล่อยแก๊สคาร์บอนไดออกไซด์มาก

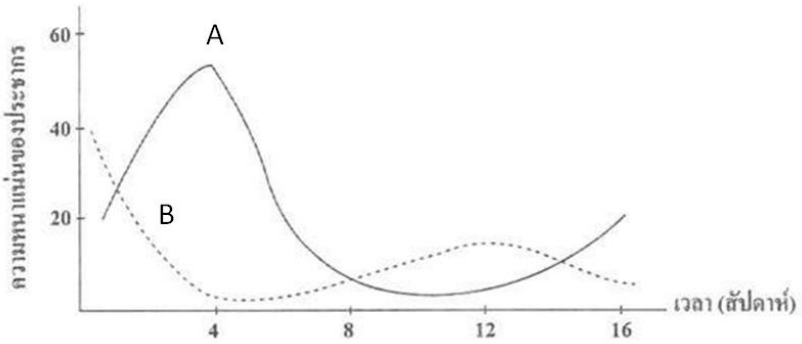
ข. ยิ่งปล่อยแก๊สคาร์บอนไดออกไซด์ออกมามากทำให้เครื่องยนต์ยิ่งมีขนาดใหญ่

ค. ปล่อยแก๊สคาร์บอนไดออกไซด์ออกมาน้อย เครื่องยนต์ยิ่งมีขนาดใหญ่

ง. ยิ่งเครื่องยนต์มีขนาดใหญ่ยิ่งทำให้ปล่อยแก๊สคาร์บอนไดออกไซด์ออกมามาก

Predicting

ข้อ 7



ที่มาของภาพ: http://www.nana-bio.com/Medium/O-net2554/O-net2553C6-C10.html

จากกราฟข้างต้นแสดงจำนวนประชากรของสิ่งมีชีวิต ชนิด A และชนิด B

ข้อใดเป็นการคาดการณ์ผลที่จะเกิดขึ้นในช่วงสัปดาห์ที่ 18 ได้ถูกต้อง

ก. A มีประชากรหนาแน่นขึ้น

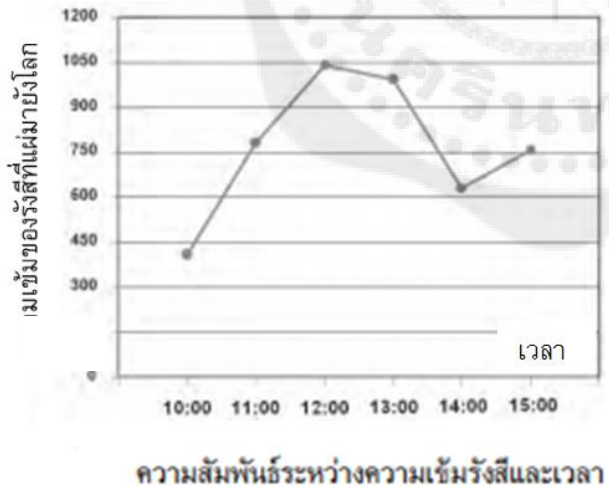
ข. B มีประชากรหนาแน่นขึ้น

ค. A และ B มีประชากรหนาแน่นเท่ากัน

ง. B มีความหนาแน่นของประชากรเป็นศูนย์

Inferring

ข้อ 8



มีนักเรียนคนหนึ่งทักท้วงว่า *"ทำไมความเข้มของแสงในเวลา 14:00 น. จึงมีค่าต่ำกว่าเวลา 15:00 น. ทั้งที่โดยปกติ เวลา 14:00 น. มักมีแสงแดดจ้ากว่าเวลา 15:00 น."*

จากข้อทักท้วงดังกล่าว นักเรียนจะให้ความเห็นว่าอย่างไร

ก. เวลา 14:00 น. อาจมีเมฆมาบดบัง

ข. เวลา 14:00 น. อาจมีลมพัดมา

ค. เวลา 14:00 น. อาจมีความชื้นอากาศสูง

ง. เฉพาะเวลา 14:00 น. ในฤดูหนาว แสงมีความเข้มน้อย

ที่มา: http://www.acat.or.th/download/acat_or_th/journal-16/16%20-%2012.pdf

Defining operationally

กุหลาบต้นที่	ความสูงของต้น (cm)	จำนวนดอก (ดอก)	จำนวนกิ่ง (กิ่ง)	ความยาวใบโดยเฉลี่ย (cm)
A	60	3	10	3.5
B	54	6	12	3.7
C	50	8	12	3.2

ข้อ 9 จากตารางบันทึกผลข้างต้น ผู้ทดลองสรุปผลว่า ต้นกุหลาบที่มีการเจริญเติบโตมากที่สุด ได้แก่ กุหลาบ C จากการสรุปดังกล่าว แสดงว่าผู้ทดลองนิยาม “การเจริญเติบโต” โดยวัดจากสิ่งใดเป็นสำคัญ

ก. ความสูงของต้น
ข. จำนวนกิ่งก้าน
ค. จำนวนดอกที่ออก
ง. ความยาวของใบโดยเฉลี่ย

Formulating hypotheses;

ข้อ 10 ในหน้าฝน หลังฝนตกจะมีแมลงเม่าจำนวนมากบินใต้หลอดไฟ
นักเรียนคนหนึ่งสงสัยว่า “ลักษณะหลอดไฟแต่ละแบบ ดึงดูดให้แมลงเม่าเข้ามาในปริมาณที่เท่ากันหรือไม่”
ข้อใดเป็นสมมติฐานที่สามารถตรวจสอบคำตอบได้

ก. หลอดไส้มีแมลงเม่ามาบินใต้หลอดไฟมากกว่าหลอดฟลูออเรสเซนต์
ข. หลอดไส้ร้อนกว่าหลอดฟลูออเรสเซนต์ทำให้แมลงเม่าบินเข้าหามากกว่า
ค. เพราะเหตุใดแมลงเม่าจำนวนมากจึงบินเข้าหาหลอดไฟ
ง. ทำไมแมลงเม่าจึงบินใต้หลอดไฟในปริมาณที่ต่างกัน

Interpreting data;

ระดับความสูงจากระดับน้ำทะเล (m)	จุดเดือด (°C)
100	98
400	97
800	96
1,200	93
1,800	91

ข้อ 11 ผลการทดลองหาจุดเดือดของของเหลวชนิดหนึ่งที่ระดับความสูงต่าง ๆ กันดังตารางที่กำหนดให้ ควรสรุปข้อมูลว่าอย่างไร

ก. จุดเดือดของของเหลวไม่คงที่
ข. ของเหลวนี้มีจุดเดือดเท่ากับน้ำ
ค. ระดับความสูงเพิ่มขึ้นจุดเดือดยิ่งต่ำ
ง. ของเหลวเดือดได้ในระดับความสูงต่างกัน

Identify and controlling variables

เนื่องจากสภาพภูมิอากาศที่ร้อนขึ้น ทำให้น้ำแข็งละลายได้ง่ายขึ้น นักเรียนคนหนึ่งสงสัยและอยากทดสอบดูว่า รูปทรงของน้ำแข็งแบบต่าง ๆจะเกิดการหลอมเหลวเร็ว-ช้าต่างกันหรือไม่ เพื่อได้นำผลการทดสอบไปสร้างแม่พิมพ์น้ำแข็งใหม่ที่ละลายช้าลง

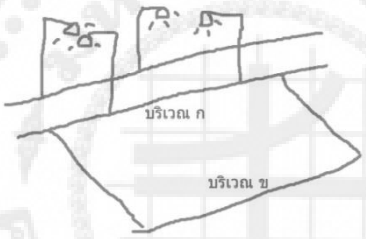
ข้อ 12 หากต้องตรวจสอบข้อสงสัยนี้ ตัวแปรต้นของการทดลองคืออะไร

ก. อุณหภูมิอากาศ
ข. รูปทรงน้ำแข็ง
ค. การละลายของน้ำแข็ง
ง. ระยะเวลาที่น้ำแข็งหลอมเหลวหมด

Experimenting

*ข้าวโพดที่แปลงสาธิตของศูนย์ศึกษาการพัฒนาอ่าวคุ้งกระเบนที่ปลูกริมทางหลวง มีการเจริญเติบโตที่ต่างกันคือ **บริเวณ ข** มีการเจริญเติบโตน้อยและแกร็นกว่าพื้นที่**บริเวณ ก** เจ้าหน้าที่ศูนย์ฯให้ความเห็นกับผู้เข้าเยี่ยมชมแปลงสาธิตว่า "น่าจะเป็นเพราะแสงไฟจากเสาไฟข้างถนนส่องตอนกลางคืน ทำให้ข้าวโพด**บริเวณ ก** เจริญเติบโตมาก"*

(ใช้ตอบคำถามข้อ 13-14)



ข้อ 13 จากข้อมูลข้างต้น เจ้าหน้าที่มีสมมติฐานเกี่ยวกับการเจริญเติบโตของต้นข้าวโพดทั้งสองบริเวณของแปลงสาธิตว่าอย่างไร

ก. ลักษณะดินบริเวณ ก และ ข ต่างกัน
ข. ปริมาณแก๊ส CO_2 บริเวณ ก และ ข ต่างกัน
ค. ความชื้นอากาศบริเวณ ก และ ข ต่างกัน
ง. ปริมาณแสงที่ได้รับบริเวณ ก และ ข ต่างกัน

ข้อ 14 หากนักเรียนต้องตรวจสอบสมมติฐานของเจ้าหน้าที่ฯดังข้างต้น นักเรียนจะออกแบบการทดลองอย่างไร

ก. นำดินจากทั้งสองบริเวณมาใส่กระถางเท่า ๆ กัน กระถางที่ 1-3 เป็นดินจากบริเวณ ก ปลูกข้าวโพด และกระถางที่ 4-6 เป็นดินจากบริเวณ ข ปลูกข้าวโพดพันธุ์เดียวกันทั้ง 6 กระถาง รดน้ำใส่ปุ๋ยและวางกระถางบริเวณเดียวกัน บันทึกการเจริญเติบโต

ข. นำดินจากแปลงสาธิตใส่กระถาง 2 กระถางเท่า ๆ กัน แล้วปลูกข้าวโพดพันธุ์เดียวกัน ให้กระถางที่ 1 ได้รับแก๊สคาร์บอนไดออกไซด์จากท่อไอเสียรถทุกเช้า ๆ ละ 10 นาที ส่วนกระถางที่ 2 วางไว้ปกติ รดน้ำใส่ปุ๋ยและวางกระถางบริเวณเดียวกัน บันทึกการเจริญเติบโต

ค. นำดินจากแปลงสาธิตใส่กระถาง 2 กระถางเท่า ๆ กัน แล้วปลูกข้าวโพดพันธุ์เดียวกัน ให้กระถางที่ 1 รดน้ำวันละ 3 ครั้ง ส่วนกระถางที่ 2 รดน้ำวันละ 1 ครั้ง ใส่ปุ๋ยและวางกระถางบริเวณเดียวกัน บันทึกการเจริญเติบโต

ง. นำดินจากแปลงสาธิตใส่กระถาง 2 กระถางเท่า ๆ กัน แล้วปลูกข้าวโพดพันธุ์เดียวกัน ให้ทั้งสองกระถาง วางบริเวณเดียวกันในตอนกลางวัน และเปิดไฟส่องกระถางที่ 2 ในตอนกลางคืน บันทึกการเจริญเติบโต

D.2 Science Competencies Test

แบบวัดสมรรถนะทางวิทยาศาสตร์

คำชี้แจงเกี่ยวกับแบบวัด

แบบวัดสมรรถนะทางวิทยาศาสตร์ (Science Competencies Test) จัดทำขึ้นเพื่อวัดระดับสมรรถนะทางวิทยาศาสตร์ ของนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1 โดยแบบวัดนี้เป็นส่วนหนึ่งของเครื่องมือวิจัย ในปริญญานิพนธ์ เรื่อง “การพัฒนารูปแบบการเรียนรู้สืบเสาะหาความรู้โดยกลวิธีทางอภิปัญญา เพื่อส่งเสริมสมรรถนะทางวิทยาศาสตร์ ทักษะกระบวนการทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1”

1. แบบวัดสมรรถนะทางวิทยาศาสตร์ มี 20 หน้า จำนวน 22 ข้อ ใช้เวลาทำข้อสอบ 1.5 ชั่วโมง

2. แต่ละข้อมีคะแนนเต็ม 3 คะแนน

3. การตอบคำถามในข้อสอบ แบ่งออกเป็น 3 ลักษณะ ดังนี้
   - 3.1 ***แบบปรนัยตัวเลือก:*** ทำเครื่องหมาย O ล้อมรอบในข้อที่เห็นว่าถูกต้องที่สุดเพียงคำตอบเดียว
   - 3.2 ***แบบปรนัยแสดงความคิดเห็น:*** ความคิดเห็นของนักเรียน ตอบทั้ง 3 คำตอบ ทำเครื่องหมาย O ล้อมรอบ ระบุว่า “ใช่”หมายถึงเห็นว่าถูกต้อง หรือ “ไม่ใช่”หมายถึงเห็นว่าไม่ถูกต้อง
   - 3.2 ***แบบเขียนตอบ:*** เขียนข้อความให้ครบถ้วนสมบูรณ์

ขอขอบคุณนักเรียนทุกคนมา ณ ที่นี้ ที่ให้ความร่วมมือในการตอบคำถามแบบวัดนี้เป็นอย่างดี

เบญญาภา ประชานันท์
(นางสาวเบญญาภา ประชานันท์)
นิสิตหลักสูตรการศึกษาดุษฎีบัณฑิต สาขาวิทยาศาสตรศึกษา
ศูนย์วิทยาศาสตรศึกษา คณะวิทยาศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ

สมรรถนะทางวิทยาศาสตร์:

ด้านการอธิบายปรากฏการณ์ทางวิทยาศาสตร์

พยากรณ์อากาศรายเดือน ประจำเดือน พฤศจิกายน 2559

คาดหมาย

ทั่วไป บริเวณความกดอากาศจากประเทศจีนจะแผ่ลงมาปกคลุมประเทศไทยตอนบนเป็นช่วง ๆ ประกอบกับมรสุมตะวันออกเฉียงเหนือพัดปกคลุมประเทศไทยตลอดเดือน และจะมีกำลังแรงเป็นช่วง ๆ โดยระยะแรก จะทำให้บริเวณประเทศไทยตอนบนมีฝนฟ้าคะนองและลมกระโชกแรงในบางพื้นที่ ต่อจากนั้นอุณหภูมิจะลดลง โดยเฉพาะภาคเหนือและภาคตะวันออกเฉียงเหนือจะมีอากาศหนาวเย็นกับมีหมอกในตอนเช้า บริเวณยอดดอยและยอดภูจะมีอากาศหนาวถึงหนาวจัดกับมีหมอกหนาในบางพื้นที่ สำหรับภาคกลางและภาคตะวันออกจะมีอากาศเย็นกับมีหมอกในตอนเช้า

อนึ่ง ร่องความกดอากาศต่ำจะเลื่อนลงไปพาดผ่านภาคใต้ตอนกลางและตอนล่าง ประกอบกับมรสุมตะวันออกเฉียงเหนือจะพัดปกคลุมภาคใต้ โดยจะมีกำลังแรงเป็นช่วงๆ ทำให้ภาคใต้จะมีฝนตกชุก กับมีฝนตกหนักถึงหนักมากบางพื้นที่ ซึ่งอาจทำให้เกิดสภาวะน้ำท่วมฉับพลัน น้ำป่าไหลหลาก และน้ำล้นตลิ่งในที่ลาดเชิงเขาและที่ลุ่มบางพื้นที่

ออกประกาศ ณ วันที่ 3 ตุลาคม 2559

ที่มา : http://www.tmd.go.th/thailand.php

วิเคราะห์ข่าวการพยากรณ์อากาศ

ตัวเลือก	ความคิดเห็นของนักเรียน	
ลมมรสุมนี้ทำให้ภาคใต้โดยเฉพาะฝั่งตะวันตกจะมีฝนตกชุก ส่วนฝั่งตะวันออกฝนตกน้อย	ใช่	ไม่ใช่
ความกดอากาศที่มาจากจีนเป็นความกดอากาศต่ำ ประกอบกับลมมรสุมตะวันออกเฉียงเหนือ จึงทำให้ภาคเหนือ กลาง อีสานของไทยอุณหภูมิลดลง	ใช่	ไม่ใช่
มีเมฆมากโดยเฉพาะทางฝั่งตะวันออกของภาคใต้ ช่วงระหว่างวันอากาศอบอ้าว ทำให้รู้สึกเหนียวเหนอะหนะกว่าปกติ	ใช่	ไม่ใช่

สมรรถนะทางวิทยาศาสตร์:

ด้านการอธิบายปรากฏการณ์ทางวิทยาศาสตร์

ทำไม ฝนมักตกในช่วงเวลาเลิกงาน ?

"ฝนราชการ" ในกรุงเทพฯและเขตปริมณฑล เพราะกรุงเทพฯ มีสภาพเป็นเกาะความร้อน (Urban heat island) ตัวเมืองเต็มไปด้วยตึก ซึ่งมีความสามารถในการกักความร้อนได้ดี กล่าวคือ ตึกหรืออาคารที่ก่อด้วยอิฐจะเก็บความร้อนจากแสงแดดในตอนกลางวัน แล้วระบายความร้อนออกในตอนกลางคืน ทำให้อากาศในเมืองเย็นตัวช้ากว่าอากาศรอบนอกตัวเมือง รวมทั้งกิจกรรมต่างๆ เช่น ความร้อนจากการเผาไหม้ของเครื่องยนต์ หรือการใช้เครื่องปรับอากาศระบายความร้อนออกจากอาคาร เป็นต้น ***ความร้อนเหล่านี้จะลอยตัวขึ้นแล้วระบายออกรอบข้าง กลายเป็นโดมที่ครอบเมืองไว้ โดยอากาศภายในโดม(ภายในเขตเมือง)จะมีอุณหภูมิค่อนข้างคงที่ อากาศภายนอกพัดเข้ามาไม่ได้หรือพัดน้อยมาก จึงทำให้เกิดการสะสมของมลพิษที่ไม่ถูกพัดไปที่อื่น*** เมื่อขับรถเข้ามาบริเวณรอยต่อระหว่างโดมความร้อน จะพบการเปลี่ยนแปลงของอุณหภูมิอากาศอย่างฉับพลัน เราอาจสังเกตขอบเขตของโดมความร้อนจากการมองขึ้นไปบนท้องฟ้า จะพบว่าท้องฟ้าบริเวณขอบและใจกลางกรุงเทพฯ มีสีต่างกัน ซึ่งเป็นเพราะฝุ่นละอองภายในเมืองที่สะท้อนแสงไฟตอนกลางคืน.... ดังนั้น การเกิดโดมความร้อนในกรุงเทพฯนี้เองที่ทำให้เกิดฝน เนื่องจากอากาศจากด้านนอกเข้ามาปะทะขอบโดม แล้วยกตัวกลายเป็น***เมฆฝน***ในกรุงเทพฯ แล้วเกิดฝนตกในกรุงเทพฯและเขตปริมณฑลบริเวณขอบของโดมความร้อน

ขณะเดียวกันความร้อนภายในเมืองยังเป็นปัจจัยเสริมให้เกิดฝนที่ตกช่วงเวลาคนเมืองเลิกงาน ที่มักเรียกกันว่า "ฝนราชการ" เนื่องจากในเขตเมืองสะสมความร้อนไว้จนสูงสุดในช่วง 15.00 น.เมื่อถึงเวลา 16.00 น.ดวงอาทิตย์คล้อยลงขอบฟ้า ทำให้ความชื้นสะสมได้มากขึ้น กอปรกับสภาพเมืองและโดมความร้อนทำให้ความร้อนไม่ระบาย จึงเกิดเมฆฝนและตกในช่วงเวลาดังกล่าว ทั้งนี้ "สภาพการสะสมความร้อนนี้เกิดขึ้นทุกที่ทั้งในเมืองและตามทุ่งนา โดยความร้อนสะสมสูงสุดช่วงเวลา 15.00 น. เหมือนกัน แต่ตามทุ่งนาหรือต่างจังหวัดมักเป็นที่โล่ง อากาศระบายได้ จึงเกิดเมฆฝนน้อยกว่า ขณะที่ในเมืองมีตึกสูงและโดมความร้อน อีกทั้งสะสมความร้อนได้สูงกว่า จึงเกิดเมฆฝนได้มากกว่า"

จากบทความ ทำไม ฝนมักตกในช่วงเวลาเลิกงาน ? ข้างต้น

ปัจจุบันเมืองใหญ่ๆแต่ละภูมิภาค มีการขยายเมืองและสิ่งก่อสร้างมากขึ้น จึงมีแนวโน้มที่จะมีสภาพเป็นโดมความร้อน เช่นกรุงเทพฯและปริมณฑลมากขึ้น และอาจมีฝนราชการมากขึ้น ถ้านักเรียนมีอำนาจในการจัดการและวางนโยบายป้องกันผลกระทบดังกล่าวให้เขตเมืองใหญ่ๆเท่านั้น จะมีแนวทางที่จะป้องกันไม่ให้เขตเมืองใหญ่ๆนั้นเกิดสภาพเป็นโดมความร้อน (Urban heat island) อย่างไรบ้าง (บอกมา 3 ประเด็น)

เขียนคำตอบ : เกณฑ์การใช้คะแนน คือ ตอบครบ 3 ประเด็น ได้ 3 คะแนน

ตัวอย่างคำตอบเช่น กล่าวถึงสมบัติของวัสดุที่นำมาก่อสร้างอาคารบ้านเรือน

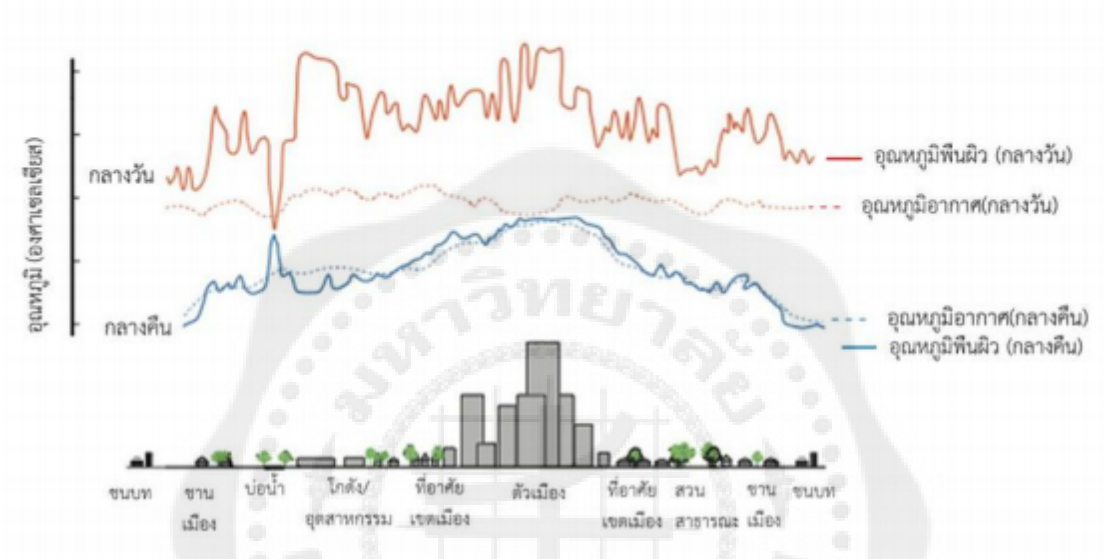
กล่าวถึงวิธีการลดแก๊สคาร์บอนไดออกไซ์

กล่าวถึงการออกแบบผังเมือง

สมรรถนะทางวิทยาศาสตร์:

ด้านการการประเมินและออกแบบกระบวนการสืบเสาะหาความรู้ทางวิทยาศาสตร์

พิจารณากราฟแสดงอุณหภูมิในเขตเมืองและชนบท ในช่วงกลางวันและกลางคืน



ที่มาของภาพ: http://www.geocoops.com/urban-microclimates.html

จากภาพจะเห็นว่า เขตเมืองมีอุณหภูมิอากาศสูงกว่าเขตชนบททั้งในเวลากลางวันและกลางคืน

ข้อใดเป็นคำถามที่สามารถตรวจสอบได้ (Testable)

ตัวเลือก	ความคิดเห็นของนักเรียน	
เขตเมืองมีปัจจัยอะไรบ้างที่ทำให้อุณหภูมิอากาศร้อนกว่าเขตชนบท	ใช่	ไม่ใช่
วัสดุที่ใช้ในการสร้างบ้านเรือนต่างกันมีผลต่อการดูดกลืนความร้อนต่างกันหรือไม่	ใช่	ไม่ใช่
ปริมาณต้นไม้มีผลต่ออุณหภูมิของอากาศในบริเวณต่างๆหรือไม่	ใช่	ไม่ใช่

สมรรถนะทางวิทยาศาสตร์:

ด้านการการประเมินและออกแบบกระบวนการสืบเสาะหาความรู้ทางวิทยาศาสตร์

สืบเนื่องจาก ด.ช.เอ อ่านข่าวทราบมาว่า น้ำฝนในปัจจุบันหลายที่มีสภาพเป็นกรด โดยน้ำฝนที่จัดว่าเป็น "ฝนกรด" นั้นต้องมีค่า pH ต่ำกว่า 5.6 และพบว่าน้ำฝนแต่ละพื้นที่ pH ต่างกัน บางพื้นที่มีค่า pH ต่ำจากน้ำฝนแต่ก่อนมาก (ซึ่งสภาพเป็นกลาง) ในเนื้อข่าวยังอธิบายถึงผลกระทบของฝนกรดว่า มีฤทธิ์กัดกร่อน ทำให้สิ่งก่อสร้างเก่าโทรม

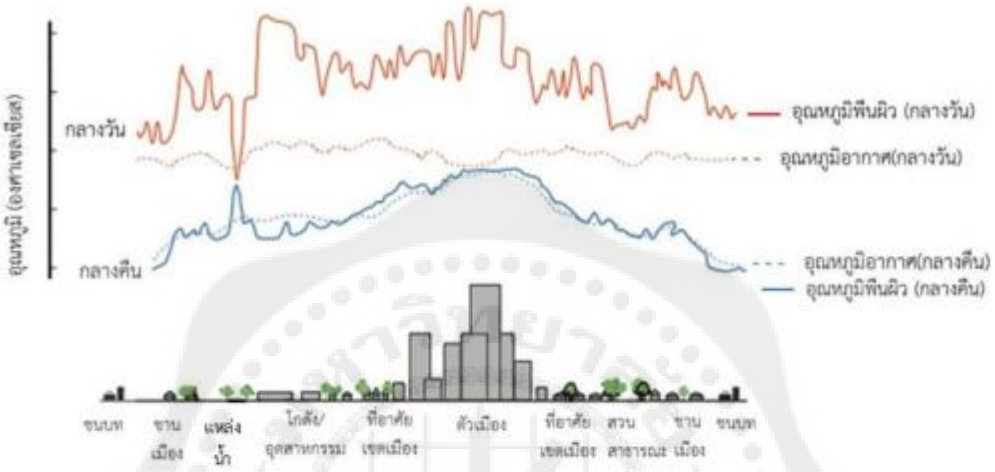
ถ้า ด.ช.เอ ต้องการทราบว่า "ฝนกรดกัดกร่อนสิ่งก่อสร้างจริงหรือไม่ และฝนกรดที่ pH มากน้อยต่างกัน ส่งผลต่อการกัดกร่อนมากน้อยแตกต่างกันหรือไม่" เขาควรออกแบบการสำรวจตรวจสอบ รวมถึงควบคุมตัวแปรอย่างไร

ตัวเลือก	ความคิดเห็นของนักเรียน	
ฝนกรด ต้องเตรียมสารละลายจากกรดคาร์บอนิกเท่านั้น	ใช่	ไม่ใช่
ต้องใส่น้ำที่ค่า pH 7 และสารละลายกรดค่า pH 5 และ pH 3 ปริมาตรเท่ากัน แล้วแช่ชิ้นหินปูนลงในบีกเกอร์นั้น	ใช่	ไม่ใช่
ต้องใช้เวลาในการแช่หินปูนทุกบีกเกอร์เท่ากัน	ใช่	ไม่ใช่

สมรรถนะทางวิทยาศาสตร์:

การแปลความหมายข้อมูลและประจักษ์พยานในเชิงวิทยาศาสตร์

กราฟแสดงอุณหภูมิพื้นผิวและอุณหภูมิอากาศในเขตเมืองและชนบท ในช่วงกลางวันกลางคืน



ที่มาของภาพ: http://www.geocoops.com/urban-microclimates.html

จากภาพจะเห็นว่า "บริเวณที่มีแหล่งน้ำ มีอุณหภูมิช่วงกลางวันต่ำสุดเมื่อเทียบกว่าพื้นที่อื่นๆ ในขณะที่ช่วงกลางคืนพบว่าบริเวณแหล่งน้ำนั้นมีอุณหภูมิสูงใกล้เคียงกับตัวเมือง"

เพื่อนของนักเรียนจึงสงสัยว่าข้อมูลในกราฟผิดพลาดหรือไม่ นักเรียนจะตอบเพื่อนว่าอย่างไร และจะอธิบายประเด็นนี้กับเพื่อนว่าอย่างไร

เขียนคำตอบ : .....

.....

.....

เกณฑ์การให้คะแนน	
ให้ 3 คะแนน	ข้อมูลถูกต้องทั้งสองแล้ว เพราะน้ำมีความสามารถในการดูด-คายความร้อน ได้ไม่ดี ทำให้กลางวันเหนือผิวน้ำอุณหภูมิต่ำ กลางคืนสูง
ให้ 2 คะแนน	ข้อมูลถูกต้อง แต่อธิบายด้วยเหตุผลอื่น เช่น ดูดกลืนไม่เท่ากัน
ให้ 1 คะแนน	ข้อมูลถูกต้อง แต่อธิบายไม่ถูกต้อง
ให้ 0 คะแนน	ข้อมูลผิดพลาดแน่นอน

สมรรถนะทางวิทยาศาสตร์:

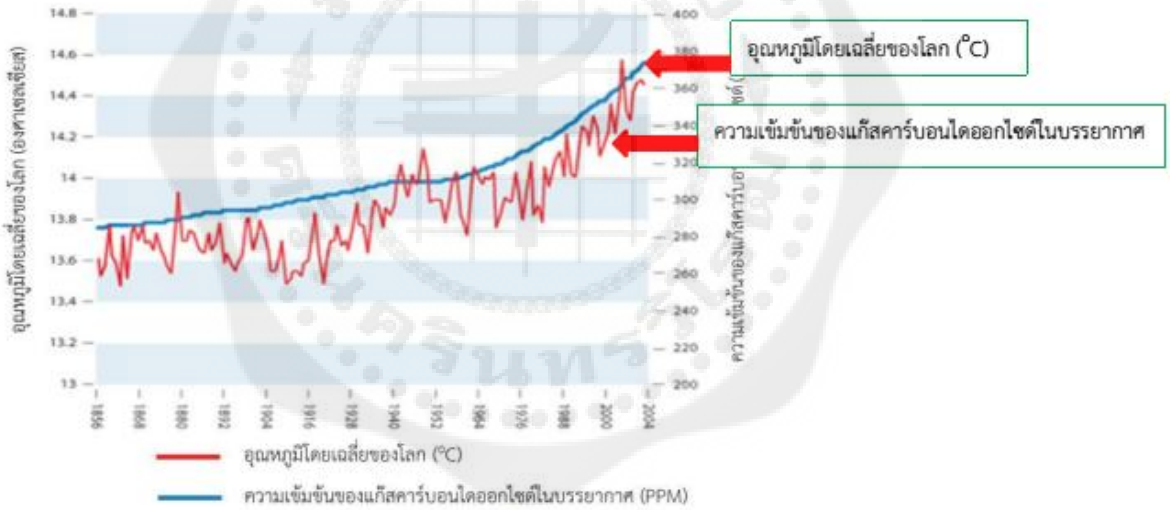
การแปลความหมายข้อมูลและประจักพยานในเชิงวิทยาศาสตร์

อ่านเรื่องต่อไปนี้แล้วตอบคำถาม

"ขณะที่พ่อและแม่มารับนักเรียนที่โรงเรียน กำลังคุยกันเรื่องจะซื้อรถยนต์อีกคันเพื่อให้แม่ขับมารับส่งนักเรียน แต่แล้วยังตกลงไม่ได้ว่าจะซื้อเครื่องยนต์ขนาดเล็ก (Eco-car) หรือขนาดใหญ่ดี? โดยให้เป็นการตัดสินใจของแม่และนักเรียนเอง ตัวนักเรียนเองไม่อยากให้ซื้อรถเพิ่มอีก เพราะเคยได้ยินมาว่าการใช้รถมาก ๆ จะทำให้เกิดภาวะโลกร้อนมากขึ้น แต่หากจำเป็นจริงๆก็ขอให้มีผลต่อภาวะโลกร้อนน้อยที่สุด จึงสนใจหาข้อมูลเกี่ยวกับความสัมพันธ์ระหว่างปริมาณคาร์บอนไดออกไซด์กับภาวะโลกร้อนว่าสัมพันธ์กันจริงหรือไม่ แล้วควรจะตัดสินใจสนับสนุนให้แม่ซื้อรถที่มีเครื่องยนต์ขนาดไหนดี?"

จากการไปศึกษาค้นคว้าข้อมูล ทำให้นักเรียนทราบว่าแก๊สคาร์บอนไดออกไซด์สามารถดูดซับคลื่นอินฟาเรด ซึ่งเป็นคลื่นความร้อนจากแสงอาทิตย์ และข้อมูลเกี่ยวกับปริมาณแก๊สชนิดนี้ในบรรยากาศในช่วงเวลาที่ผ่านมา ตลอดจนข้อมูลการปลดปล่อยแก๊สคาร์บอนไดออกไซด์จากเครื่องยนต์ขนาดต่าง ๆ ดังกราฟด้านล่าง

อุณหภูมิของโลกและความเข้มข้นของแก๊สคาร์บอนไดออกไซด์บนโลก (ค.ศ. 1856 – 2004)



ที่มา: http://www.livesmartbc.ca/learn/change.html

จากข้อมูลข้างต้น นักเรียนคิดว่าแก๊สคาร์บอนไดออกไซด์ที่ปล่อยออกมามีผลต่อภาวะโลกร้อนหรือไม่ อย่างไร จงอธิบายเหตุผล พร้อมระบุหลักฐานสนับสนุนจากข้อมูลข้างต้น

เขียนคำตอบ : .....

	เกณฑ์การให้คะแนน
ให้ 3 คะแนน	มีผล เพราะแก๊สคาร์บอนไดออกไซด์มีสมบัติดูดความร้อนจากรังสีอินฟราเรด ดังจะเห็นได้จากเส้นกราฟที่แปรผันตรงกับอุณหภูมิ ปริมาณแก๊สคาร์บอนไดออกไซด์ที่เพิ่มขึ้น อุณหภูมิเฉลี่ยของโลกก็เพิ่มขึ้นในทิศทางที่สอดคล้องกัน และพบว่าเพิ่มสูงขึ้นเรื่อยๆจากอดีตจนถึงปัจจุบัน ใช้หลักฐานจากกราฟอธิบายสอดคล้องทั้งสองเส้นกราฟ
ให้ 2 คะแนน	มีผล ดูจากกราฟ
ให้ 1 คะแนน	มีผล
ให้ 0 คะแนน	ตอบว่าไม่มีผล หรือตอบด้วยเหตุผลอื่น

D.3 Self-efficacy in Science Test

แบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์

คำชี้แจงเกี่ยวกับแบบวัด

แบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์ (Self-efficacy in Science Test) จัดทำขึ้นเพื่อวัดระดับการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1 โดยแบบวัดนี้เป็นส่วนหนึ่งของเครื่องมือวิจัย ในปริญญานิพนธ์ เรื่อง “การพัฒนารูปแบบการเรียนรู้สืบเสาะหาความรู้โดยกลวิธีทางอภิปัญญา เพื่อส่งเสริมสมรรถนะทางวิทยาศาสตร์ ทักษะกระบวนการทางวิทยาศาสตร์ และการรับรู้ความสามารถทางวิทยาศาสตร์ ของนักเรียนระดับชั้นมัธยมศึกษาปีที่ 1”

1. แบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์ (Self-efficacy in Science Test) นี้
   มี 5 หน้า ประกอบด้วย 2 ตอน ได้แก่
   ตอนที่ 1 ข้อมูลของนักเรียน
   ตอนที่ 2 ข้อมูลการรับรู้ความสามารถทางวิทยาศาสตร์

2. ใช้เวลาทำแบบวัด 25 นาที
3. แบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์ ประกอบข้อคำถาม จำนวน 41 ข้อ และมีระดับ ความคิดเห็นต่อข้อคำถาม 5 ระดับ ให้นักเรียนทำเครื่องหมาย O ล้อมรอบตัวเลขที่ตรงกับความคิดเห็นมากที่สุด
4. การตอบแบบวัดการรับรู้ความสามารถทางวิทยาศาสตร์นี้ จะไม่มีผลเสียใด ๆ ต่อผลการเรียนของนักเรียน ข้อมูลที่ได้จากแบบวัดนี้ จะใช้สำหรับการวิจัยครั้งนี้เท่านั้น

ขอขอบคุณนักเรียนทุกคนมา ณ ที่นี้ ที่เสียสละเวลาและให้ความร่วมมือในการตอบคำถามแบบวัดนี้เป็นอย่างดี

เบญญาภา ประชานันท์
(นางสาวเบญญาภา ประชานันท์)
นิสิตหลักสูตรการศึกษาดุษฎีบัณฑิต สาขาวิทยาศาสตรศึกษา
ศูนย์วิทยาศาสตรศึกษา คณะวิทยาศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ

ชื่อ – สกุล.....ชั้น ม...../ ..... เลขที่ ..... โรงเรียน.....

<u>ส่วนที่ 1</u> ข้อมูลของนักเรียน

1. **เพศ** ☐ หญิง ☐ ชาย
2. **อายุ** ☐ ต่ากว่า 13 ปี ☐13 ปี ☐ 14 ปี ☐ 15 ปี

<u>ส่วนที่ 2</u> ข้อมูลการรับรู้ความสามารถทางวิทยาศาสตร์ เรื่อง บรรยากาศและลมฟ้าอากาศ

5 หมายถึง เห็นด้วยอย่างยิ่ง 4 หมายถึง เห็นด้วย 3 หมายถึง ไม่แน่ใจ

2 หมายถึง ไม่เห็นด้วย 1 หมายถึง ไม่เห็นด้วยอย่างยิ่ง

	ระดับความคิดเห็น				
	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่แน่ใจ	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
1. ฉันมั่นใจว่าสามารถอธิบายปรากฏการณ์ต่าง ๆ ที่เกิดขึ้นในชั้นบรรยากาศแต่ละชั้นของโลกได้	5	4	3	2	1
2. ฉันไม่สามารถอธิบายสาเหตุที่ทำให้เกิดภาวะโลกร้อนได้	5	4	3	2	1
3. ฉันมั่นใจว่าสามารถคำนวณโจทย์ปัญหาเกี่ยวกับความดันอากาศ ความชื้นอากาศได้ถูกต้อง	5	4	3	2	1
4. ฉันมั่นใจว่าสามารถอธิบายสาเหตุที่ทำให้อุณหภูมิในช่วงเช้า กลางวัน และเย็นแตกต่างกันได้	5	4	3	2	1
5. ฉันมั่นใจว่าสามารถบอกได้ว่าการใช้รถที่มีเครื่องยนต์ขนาดเล็กและใหญ่ ส่งผลต่อการเกิดปรากฏการณ์เรือนกระจกแตกต่างกันอย่างไร	5	4	3	2	1
6. ฉันมั่นใจว่าสามารถเชื่อมโยงข้อมูลจากหลายแหล่ง เพื่ออธิบายปรากฏการณ์ทางลมฟ้าอากาศได้ถูกต้อง	5	4	3	2	1
7. ฉันมั่นใจว่าสามารถอธิบายปรากฏการณ์รูโหว่โอโซน ฝนกรด ต่อสิ่งมีชีวิตและสิ่งแวดล้อมได้	5	4	3	2	1
8. ฉันมั่นใจว่าสามารถอธิบายหลักการเกิดลมได้ถูกต้อง	5	4	3	2	1
9. เมื่อฉันเห็นเมฆปรากฏ ฉันมั่นใจว่าสามารถบอกได้ว่าเป็นเมฆก่อให้เกิดฝน	5	4	3	2	1
10. ฉันมั่นใจว่าสามารถอธิบายถึงสาเหตุที่ทำให้เขตบางขุนเทียนหรือพื้นที่เรียบฝั่งทะเล มีน้ำทะเลล้ำเข้ามาผืนดินมากกว่าอดีต	5	4	3	2	1

	ระดับความคิดเห็น				
	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่แน่ใจ	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
11. ฉันจะล้มเลิกการหาคำตอบ เมื่อพบว่าต้องใช้กระบวนการที่ยากหลายขั้นตอนในการหาคำตอบนั้น	5	4	3	2	1
12. ฉันมั่นใจว่าสามารถออกแบบการทดลองใด ๆ ที่เกี่ยวกับปรากฏการณ์ลมฟ้าอากาศ (เช่น ผลกระทบจากฝนกรด) ได้	5	4	3	2	1
13. ฉันมั่นใจว่าสามารถใช้ความรู้ทางวิทยาศาสตร์ที่เรียนมา เสนอแนวทางแก้ไขที่หลากหลายเพื่อแก้ปัญหาเกี่ยวกับลมฟ้าอากาศและสิ่งแวดล้อม	5	4	3	2	1
14. เมื่อพบปัญหาวิทยาศาสตร์ใด ๆ เกี่ยวกับบรรยากาศ ลมฟ้าอากาศ ฉันมั่นใจว่าสามารถสร้างสมมติฐานที่นำไปสู่การทดลองตรวจสอบหาคำตอบได้ (Testable)	5	4	3	2	1
15. ไม่ว่าปัญหาใด ๆ ฉันมั่นใจว่าสามารถใช้ทักษะกระบวนการทางวิทยาศาสตร์ที่เรียนมา สืบเสาะหาคำตอบปัญหาให้สำเร็จได้	5	4	3	2	1
16. เมื่อต้องออกแบบการทดลองด้วยตนเอง ฉันมั่นใจว่าสามารถบอกขั้นตอนและเหตุผลที่ต้องจัดกระทำในขั้นตอนนั้น ๆ ได้	5	4	3	2	1
17. เมื่อต้องทำการทดลองเปรียบเทียบความสามารถในการดูดรังสีความร้อนของวัสดุ ต่าง ๆ บนโลก ฉันมั่นใจว่าสามารถระบุอุปกรณ์เครื่องมือที่ต้องใช้ทั้งหมดได้ถูกต้อง	5	4	3	2	1
18. ฉันไม่มั่นใจเกี่ยวกับวิธีการใช้เครื่องมืออุปกรณ์การทดลองในห้องปฏิบัติการ	5	4	3	2	1
19. เมื่อต้องทำการทดลองใด ๆ เช่น ฝนกรดและผลกระทบของฝนกรด การดูดและคายความร้อนของสาร ฉันมั่นใจว่าสามารถระบุข้อมูลที่ต้องเก็บรวบรวม เพื่อนำมาใช้เป็นหลักฐานยืนยันในการสรุปผล	5	4	3	2	1
20. ฉันมั่นใจว่าสามารถใช้ความมุ่งมั่นพยายามทำงานวิทยาศาสตร์ใด ๆ ให้สำเร็จได้	5	4	3	2	1
21. ถ้ามีการทำการทดลองเกี่ยวกับลมฟ้าอากาศทั้งแบบยาก-ง่ายหลากหลายให้เลือก ฉันมั่นใจว่าจะเลือกทำการทดลองที่ยากท้าทายความสามารถตนเอง	5	4	3	2	1

	ระดับความคิดเห็น				
	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่แน่ใจ	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
22. เมื่อมีนโยบายปรับผังเมืองใหม่ จัดให้พื้นที่ส่วนใหญ่ปลูกต้นไม้สร้างสวนสาธารณะแทนการสร้างห้างสรรพสินค้า ฉันจะไม่สนับสนุนนโยบายนี้	5	4	3	2	1
23. ฉันมั่นใจว่าสามารถประเมินสาเหตุ/ระบุความเป็นไปได้เกี่ยวกับเหตุการณ์ทางลมฟ้าอากาศ เช่น ฟ้าผ่า ได้จากข้อมูลที่ปรากฏในข่าว	5	4	3	2	1
24. ฉันมั่นใจว่าสามารถใช้ความรู้เรื่องการเกิดลม ในการระบุตำแหน่งที่เหมาะสมในการติดตั้งประตูหรือหน้าต่างเพื่อให้ลมพัดผ่านห้องได้สะดวก	5	4	3	2	1
25. เมื่อฟังข่าวพยากรณ์อากาศที่มีข้อมูลหย่อมความกดอากาศสูงต่ำแล้ว ฉันมั่นใจว่าสามารถบอกเกี่ยวกับอุณหภูมิในพื้นที่ดังกล่าวได้	5	4	3	2	1
26. ฉันสามารถทำความเข้าใจข่าวหรือบทความเกี่ยวกับลมฟ้าอากาศที่ปรากฏในสื่อ ต่าง ๆ ได้	5	4	3	2	1
27. ฉันรู้วิธีการเตรียมตัวและปฏิบัติตัว เมื่อร่างกายต้องอยู่ในที่ ๆ มีความดันอากาศเปลี่ยนไปจากเดิม เช่น เทือกเขา บนเครื่องบิน หรือหุบเขา	5	4	3	2	1
28. ฉันมั่นใจว่าสามารถนำความรู้เรื่อง การสะท้อนและดูดกลืนรังสีจากดวงอาทิตย์ของวัสดุ เป็นแนวทางในการตัดสินใจเลือกทาสีบ้านเพื่อลดความร้อนของบ้านได้	5	4	3	2	1
29. เมื่อฉันฟังข่าวเกี่ยวกับลมมรสุมตะวันออกเฉียงเหนือและมรสุมตะวันตกเฉียงใต้พัดผ่านบริเวณที่ฉันอาศัยอยู่ (กรุงเทพ) ฉันมั่นใจว่าสามารถคาดการณ์สภาพอากาศที่จะเกิดขึ้นได้	5	4	3	2	1
30. ฉันมั่นใจว่าสามารถใช้ทักษะการสังเกตและความรู้ที่เรียนแล้ว ทำความเข้าใจ กราฟ แผนภาพ หรือแหล่งข้อมูลอื่นเกี่ยวกับลมฟ้าอากาศหรือสิ่งที่พบเห็นในชีวิตประจำวันอื่น ๆ ได้	5	4	3	2	1
31. จากข้อโต้แย้งว่า “โรงไฟฟ้านิวเคลียร์ในไทยเหมาะสมหรือไม่” ฉันจะสนับสนุนให้มีโรงไฟฟ้านิวเคลียร์ เนื่องจากจะช่วยลดภาวะโลกร้อนได้	5	4	3	2	1

	ระดับความคิดเห็น				
	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่แน่ใจ	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
32. ฉันมั่นใจว่าสามารถระบุข้อมูลหลักฐานที่ใช้ยืนยันว่ารถยนต์ที่มากขึ้นส่งผลกระทบต่อการเกิดภาวะโลกร้อนที่มากขึ้นได้	5	4	3	2	1
33. ฉันมั่นใจว่าสามารถใช้ความรู้ที่เรียนมา เลือกช่วงเวลาที่จะไปเที่ยวทะเลฝั่งอันดามันได้โดยไม่เจอลมมรสุมฝนตกได้	5	4	3	2	1
34. เมื่อต้องโต้แย้งหรือสนับสนุนประเด็นเกี่ยวกับลมฟ้าอากาศของโลก ฉันมั่นใจว่าสามารถเลือกใช้ข้อมูลหลักฐานมามาสนับสนุนหรือโต้แย้งได้	5	4	3	2	1
35. เมื่อเพื่อนนำเสนองานจบ ฉันสามารถร่วมอภิปรายและเสนอแนะในประเด็นที่เพื่อนนำเสนอได้	5	4	3	2	1
36. ฉันสามารถพูดนำเสนอประเด็นต่าง ๆ ตรงตามเป้าหมายที่ฉันวางแผนไว้ ได้ครบประเด็น	5	4	3	2	1
37. เมื่อมีข้อมูลกราฟนำเสนอเกี่ยวกับลมฟ้าอากาศ (แปรปรวน) ในปัจจุบัน ฉันมั่นใจว่าสามารถอธิบายข้อมูลในกราฟนั้นให้เพื่อนเข้าใจได้	5	4	3	2	1
38. ฉันมั่นใจว่าสามารถเขียนสื่อความบอกแนวคิดเกี่ยวกับบรรยากาศ ลมฟ้าอากาศที่เรียนแล้วได้ตรงตามที่ฉันคิดนำเสนอ	5	4	3	2	1
39. ฉันมั่นใจว่าสามารถเลือกใช้วิธีการนำเสนอข้อมูลที่เหมาะสมกับเนื้อหาและเข้าใจง่ายได้	5	4	3	2	1
40. เมื่อต้องอภิปรายหรือแสดงความคิดเห็นต่องาน ฉันมั่นใจว่าสามารถนำเสนอได้โดยมีหลักฐานและเหตุผลประกอบชัดเจน	5	4	3	2	1
41. ฉันรู้สึกไม่สบายใจ หากต้องพูดหรืออธิบายสิ่งที่เกี่ยวข้องกับบรรยากาศ ลมฟ้าอากาศที่เรียนมาแล้วให้เพื่อนฟัง	5	4	3	2	1

APPENDIX E

The results of students' mean score on science process skills among seventh, eighth and ninth grader

Data were analyzed by ANOVA in order to compare mean score of students' science process skills among grade levels. The results of students' science process skills among grade levels revealed that it was different mean scores between groups on overall and has found in almost skills (see table 1E).

TABLE 1E The comparison results of students' mean score on science process skills among seventh, eighth and ninth grader

		Sum of Squares	df	Mean Square	F	Sig.
Overall 13 skills	Between groups	3090.750	2	1545.375	33.755	.000**
	Within groups	19365.853	423	45.782		
	Total	22456.603	425			
1.Observing	Between groups	.154	2	.077	.151	.086
	Within groups	215.086	423	.508		
	Total	215.239	425			
2.Classifying	Between groups	6.880	2	3.440	6.355	.002*
	Within groups	228.970	423	.541		
	Total	235.850	425			
3.Measuring	Between groups	.698	2	.349	.415	.661
	Within groups	355.746	423	.841		
	Total	356.444	425			
4.Using space/time relationship	Between groups	24.287	2	12.144	9.437	.000**
	Within groups	544.333	423	1.287		
	Total	568.620	425			
5.Using number	Between groups	11.616	2	5.808	6.097	.002*
	Within groups	402.966	423	.953		
	Total	414.582	425			
6.Communicating	Between groups	26.085	2	13.043	11.362	.000**
	Within groups	485.567	423	1.148		
	Total	511.653	425			

		Sum of Squares	df	Mean Square	F	Sig.
7.Predicting	Between groups	11.883	2	5.941	12.214	.000**
	Within groups	205.763	423	.486		
	Total	217.646	425			
		Sum of Squares	df	Mean Square	F	Sig.
8.Inferring	Between groups	30.971	2	15.486	12.589	.000**
	Within groups	520.325	423	1.230		
	Total	551.296	425			
9.Defining operationally	Between groups	35.330	2	17.665	20.749	.000**
	Within groups	360.128	423	.851		
	Total	395.458	425			
10.Formulating hypotheses	Between groups	8.067	2	4.034	8.145	.000**
	Within groups	209.482	423	.495		
	Total	217.549	425			
11.Interpreting data	Between groups	39.092	2	19.546	20.779	.000**
	Within groups	397.894	423	.941		
	Total	436.986	425			
12.Identify and controlling variables	Between groups	50.268	2	25.134	25.680	.000**
	Within groups	413.998	423	.979		
	Total	464.265	425			
13.Experimenting	Between groups	100.985	2	50.492	34.148	.000**
	Within groups	625.459	423	1.479		
	Total	726.444	425			

* $p < 0.05$

** $p < 0.01$

Post Hoc test in terms of Scheffe [a,b] showed the overall score was not statistically significant different between seventh and eighth grade students while it had found statistically significant different between eighth and ninth grade students (see Table 2E). In addition, it revealed that almost students' mean score on each skill was found the same trend.

TABLE 2E Scheffe [a,b] on the comparison of overall science process skills

Overall 13 skills		N	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	18.169	
	8	113		23.814
	7	189		24.249
	Sig.		1.000	.858

Seventh grade students were placed at the highest among the groups. Unfortunately, the students' mean score was decreasing by grade level. Moreover, Scheffe [a,b] showed not statistically significant different between seventh and eighth grade students while it had found significance between eighth and ninth grade students in ten skills consisted of classifying, using space/time relationship, using number, predicting, communicating, inferring, defining operationally, interpreting data, identify and controlling variables skills, and formulating hypotheses and ninth grade students became lowest mean scores among the groups. Scheffe [a,b] showed not statistically significant different among three grade level in two skills namely observing, measuring, and it showed statistically significant different among three grade level in experimental skill which seventh grader were placed at highest mean score and was decreasing at higher grade level. (See Table 3E and Figure 1E)

TABLE 3E Scheffe [a,b] on each science process skill

1.Observing		n	Subset for alpha = 0.05
	Grade Levels		1
Scheffe [a,b]	7	189	0.936
	8	113	0.973
	9	124	0.975
	Sig.		.893

2.Classifying		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	0.822	
	8	113		1.070
	7	189		1.116
	Sig.		1.000	.867

3.Measuring		n	Subset for alpha = 0.05
	Grade Levels		1
Scheffe [a,b]	9	124	2.024
	7	189	2.079
	8	113	2.132
	Sig.		.594

4.Using space/time relationship		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.935	
	7	189		2.269
	8	113		2.575
	Sig.		1.000	.070

5.Using number		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.411	
	7	189		1.698
	8	113		1.840
	Sig.		1.000	.455

6.Communicating		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	2.741	
	7	189		3.238
	8	113		3.345

	Sig.		1.000	.690
7.Predicting		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.072	
	8	113		1.371
	7	189		1.465
	Sig.		1.000	.510
8.Inferring		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.903	
	7	189		2.492
	8	113		2.504
	Sig.		1.000	.995
9.Defining operationally		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.153	
	8	113		1.637
	7	189		1.836
	Sig.		1.000	.181
10.Formulating hypotheses		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	0.645	
	8	113		0.929
	7	189		0.957
	Sig.		1.000	.941
11.Interpreting data		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	1.322	
	8	113		1.902

	7	189		2.026
	Sig.		1.000	.546
12.Identify and controlling variables		n	Subset for alpha = 0.05	
	Grade Levels		1	2
Scheffe [a,b]	9	124	0.959	
	8	113		1.548
	7	189		1.772
	Sig.		1.000	.152

13.Experimenting		n	Subset for alpha = 0.05		
	Grade Levels		1	2	3
Scheffe [a,b]	9	124	1.201		
	8	113		1.982	

13.Experimenting		n	Subset for alpha = 0.05		
	Grade level		1	2	3
	7	189			2.359
	Sig.		1.000	1.000	1.000

A. Not difference among grade level	B. Partial difference In some grade levels		C. Difference among all grade levels		
7th 8th 9th grade	7th 8th grade	9th grade	7th	8th	9th
Observing Measuring	Communicating Inferring Interpreting data Defining operationally Identify and controlling variables Formulating hypotheses Classifying Using number Predicting Using space/time relationship		Experimental		

VITAE

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