

THE DEVELOPMENT OF WARM TEMPERATURE ADAPTED BREEDING POOL (WTABP)
OF WISCONSIN FAST PLANTS TO PROMOTE SCIENTIFIC INVESTIGATION SKILLS
FOR EIGHTH GRADE STUDENTS



DISSERTATION
BY
BUNYARAT KANHATHAISONG

Presented in Partial Fulfillment of the Requirements for the
Doctor of Education Degree in Science Education
at Srinakharinwirot University

June 2012

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Bunyarat Kanhathaisong. (2012). *A Development of Warm Temperature Adapted Breeding Pool (WTABP) of Wisconsin Fast Plants to Promote Scientific Investigation Skills for Eighth Grade Students*. Dissertation, Ed.D. (Science Education). Bangkok: Graduate School, Srinakharinwirot University. Advisor Committee: Assoc. Prof. Dr. Parin Chaivisuthangkura, Assoc. Prof. Dr. Somson Wongyounoi, Acting Sub Lt. Dr. Manat Boonprakob, Dr. Precharn Dechsri.

This study aimed to develop the Warm Temperature Adapted Breeding Pool (WTABP) of Wisconsin Fast Plants, and to study learning outcomes of the students who studied through the Warm Temperature Adapted Breeding Pool (WTABP) of Wisconsin Fast Plants activity including scientific inquiry skills, understanding of nature of scientific inquiry, understanding of nature of science, and attitude towards science.

Research methodology consisted of two phases: 1) development of biological instructional materials and 2) research on students' ability to conduct scientific inquiry, understand nature of scientific inquiry, and understand nature of science. In phase one, rapid cycling *Brassica rapa* (Wisconsin Fast Plants) was adapted to warm temperature of Thailand. Four experiments: temperature shifting 1, temperature shifting 2, ventilation system, and ambient temperature were conducted in order to adapt the plants to grow and reproduce in warm temperature. The result showed that the plants could grow and reproduce in warm temperature up to 32°C. In phase two, the adapted plants were used incorporated with scientific inquiry teaching method in order to study students' scientific inquiry skills, understanding of nature of scientific inquiry, understanding of nature of science, and students' attitude towards science. Four rapid cycling of *B. rapa* activities were developed based on scientific inquiry method and examined by the experts on the basis of their appropriateness. The activities were trialed with 30 eighth grade students from Chaturatwittayakarn school before the implementation. The activities were implemented with 40 eighth grade students from the same school but different class. Data collection included pre-test and post-test of students' scientific inquiry skills score, students' understanding of nature of scientific inquiry, and students' understanding of nature of science. The students' attitude towards science was collected after the activities.

The research finding showed that after doing the scientific inquiry with rapid cycling *B. rapa* activities, the students score from the scientific inquiry skills test and the nature of scientific inquiry test were higher than the criterion score at the 0.05 level of significance. Students' attitude towards science was at a high level. However, students' understanding of nature of science was not affected.



การพัฒนาพิชฌวัตชีวิตสั้นเพื่อใช้เป็นสื่อการเรียนรู้ที่ส่งเสริมทักษะการสืบเสาะหาความรู้ทาง
วิทยาศาสตร์สำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 2



เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา
ตามหลักสูตรปริญญาการศึกษาดุขฎีบัณฑิต สาขาวิชาวิทยาศาสตร์ศึกษา
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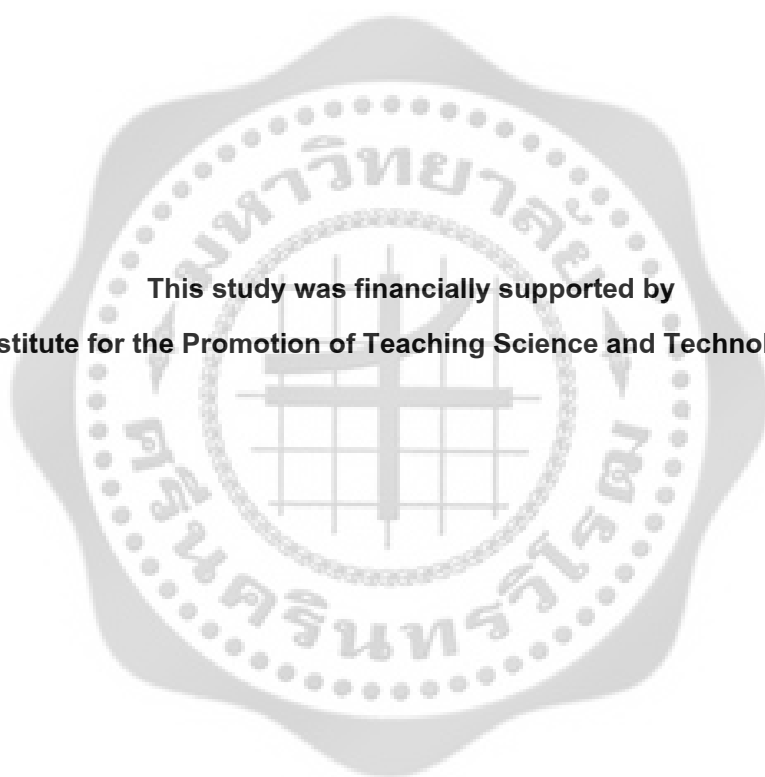
บุญรัตน์ กัณฑ์ไชยวงศ์. (2555). การพัฒนาพืชวงศ์ Brassica rapa เพื่อใช้เป็นสื่อการเรียนรู้ที่ส่งเสริมทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์สำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 2. ปรินทิพย์. กศ.ด. (วิทยาศาสตร์ศึกษา). กรุงเทพฯ : บัณฑิตวิทยาลัย. มหาวิทยาลัย ศรีนครินทรวิโรฒ กรรมการควบคุม: รศ.ดร.ปริญทร์ ชัยวิสุทธิทางกูร, รศ.ดร.สมสรร วงษ์อยู่น้อย, ว่าที่ร้อยตรี ดร.มนัส บุญประกอบ, ดร.ปรีชาญ เดชศรี.

การศึกษานี้มีจุดมุ่งหมายเพื่อพัฒนาพืชวงศ์ Brassica rapa เพื่อใช้เป็นสื่อที่ส่งเสริมทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ของนักเรียนชั้นมัธยมศึกษาตอนต้น และศึกษาผลการเรียนรู้ของนักเรียนที่ผ่านการเรียนรู้ด้วยการทำกิจกรรมการสืบเสาะหาความรู้โดยใช้พืชโตเร็วที่พัฒนาขึ้นในด้านทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ ความเข้าใจธรรมชาติของการสืบเสาะหาความรู้ทางวิทยาศาสตร์ ความเข้าใจธรรมชาติวิทยาศาสตร์ และเจตคติต่อวิทยาศาสตร์

กระบวนการศึกษาวิจัยแบ่งเป็น 2 ระยะ คือ ระยะที่ 1 การพัฒนาสื่อการเรียนรู้ทางด้านชีววิทยา และระยะที่ 2 การศึกษาทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ ความเข้าใจธรรมชาติของการสืบเสาะหาความรู้ทางวิทยาศาสตร์ ความเข้าใจธรรมชาติวิทยาศาสตร์ และเจตคติต่อวิทยาศาสตร์ ในระยะที่ 1 เป็นการพัฒนาปรับปรุงสายพันธุ์พืชโตเร็วให้สามารถเจริญเติบโตและขยายพันธุ์ได้ในสภาพอากาศของประเทศไทย ประกอบด้วย 4 การทดลอง ได้แก่ การปรับเหมาะอุณหภูมิครั้งที่ 1 การปรับเหมาะอุณหภูมิครั้งที่ 2 การใช้ระบบระบายอากาศ และการปลูกในสภาพจริง ผลการศึกษาพบว่า พืชวงศ์ Brassica rapa สามารถทนอุณหภูมิสูงได้ถึง 32 องศาเซลเซียส ในระยะที่ 2 การนำพืชที่ได้รับการปรับปรุงสายพันธุ์แล้วมาใช้เป็นสื่อการเรียนรู้ที่ส่งเสริมทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ กิจกรรมพืชวงศ์ Brassica rapa ที่สร้างขึ้นมี 4 กิจกรรม ซึ่งได้รับการประเมินด้านความเหมาะสมและความสอดคล้องจากผู้เชี่ยวชาญ และได้นำไปทดลองใช้กับนักเรียนชั้นมัธยมศึกษาปีที่ 2 จำนวน 30 คนจากโรงเรียนจตุรัสวิทยาคารเพื่อพัฒนาคุณภาพของกิจกรรมและรวบรวมข้อมูลเพื่อใช้ในการกำหนดเกณฑ์สำหรับการทดสอบสมมติฐาน และได้นำกิจกรรมที่ได้รับการปรับปรุงแล้วไปใช้กับนักเรียนชั้นมัธยมศึกษาปีที่ 2 จำนวน 40 คนจากโรงเรียนจตุรัสวิทยาคารเช่นเดียวกัน ข้อมูลที่ได้รับจากการใช้กิจกรรมพืชวงศ์ Brassica rapa ประกอบด้วย คะแนนทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ คะแนนความเข้าใจธรรมชาติของการสืบเสาะหาความรู้ทางวิทยาศาสตร์ คะแนนความเข้าใจธรรมชาติวิทยาศาสตร์จากการสอบก่อนและหลังการใช้กิจกรรม และคะแนนเจตคติต่อวิทยาศาสตร์หลังการใช้กิจกรรม

ผลการวิจัยพบว่า ภายหลังจากทำกิจกรรมการสืบเสาะหาความรู้ทางวิทยาศาสตร์โดยใช้พืชวงศ์ Brassica rapa นักเรียนมีคะแนนทักษะการสืบเสาะหาความรู้ทางวิทยาศาสตร์ และคะแนนความเข้าใจธรรมชาติของการสืบเสาะหาความรู้ทางวิทยาศาสตร์สูงกว่าเกณฑ์ที่กำหนดไว้อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 เจตคติต่อวิทยาศาสตร์ของนักเรียนอยู่ในระดับสูง ส่วนคะแนนความเข้าใจธรรมชาติวิทยาศาสตร์ของนักเรียนต่ำกว่าคะแนนจุดตัดที่กำหนดไว้

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The dissertation titled
“The Development of Warm Temperature Adapted Breeding Pool (WTABP) of Wisconsin Fast
Plants to Promote Scientific Investigation Skills for Eighth Grade Students”

By
Bunyarat Kanhathaisong

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Bunyarat Kanhathaisong

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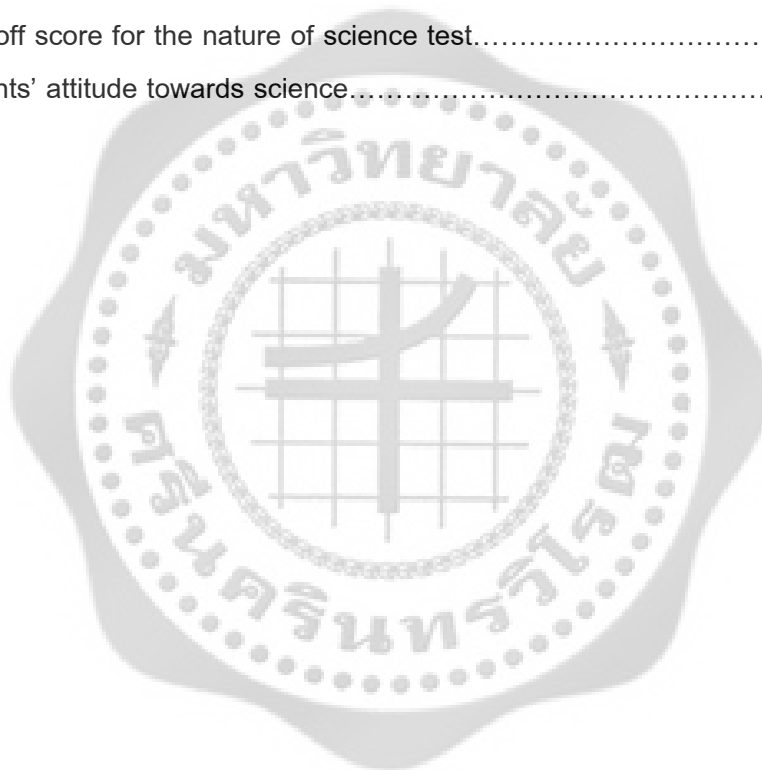
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CHAPTER 1

INTRODUCTION

1. Background

The 1999 National Education Act (NEA) and amendment 2002 serve as a basis for the education reform of Thailand. One important aspect in the NEA is learning reform. The main goals of which are to help students to: develop their independent thinking and analytical skills, promote the development of their science process skills, and enhance their understanding of the scientific method, and increase their problem solving skills (ONEC. 1999). These skills are very important for improving students' science learning and these will be used to solve problems faced in their everyday life.

The Ministry of Education of Thailand stated in the Basic Education Core Curriculum that Science plays an important role in our present and future world communities, as it concerns all of us in our daily lives and livelihood. Science enables us to develop our thinking skills in various respects—logical, creative, analytical and critical. It also enables us to acquire essential investigative skills for seeking knowledge, and allows the ability for systematic problem-solving, and for verifiable decision-making based on diverse data and evidence. Science is essential to the modern world, which is intrinsically a knowledge society (The Ministry of Education. 2008: 106).

A consequence of recent education reform in Thailand is the implementation of inquiry-based science research programs by many schools. In such programs, students conduct independent and authentic investigations. In order to better understand the process of science and to broaden their content knowledge, students must be immersed in realistic investigations through the process of scientific inquiry where students can deepen their scientific knowledge and develop new understanding of the nature of science. (Meyer & Crawford. 2010: 1-22)

Schools should function more effectively if they cover less content and do so in a way that would allow students to build a deeper understanding of how scientific knowledge claims and theories are constructed. This would be of use to all students in their decision making outside of school, and to those pursuing studies in science as well.

Many science textbooks portray science as a collection of facts or a body of knowledge for students to learn. Unfortunately, this may leave students with the impression that studying science is nothing more than memorizing facts and theories. In fact, there is

much room in science for intuitive, hypothetical, playful, and imaginative forms of learning. In other words, there is room for inquiry in which students are in control of an important part of their own learning where they can manipulate ideas to increase their understanding. As students learn to think through the design and developments of their own inquiry, they also develop a sense of self-responsibility that transcends science.

In order for students to understand the nature of science, teachers must establish an appropriate teaching and learning environment for their students. One effective strategy is through scientific investigation: asking and refining questions; seeking background information; making predictions; designing investigations; collecting, analyzing, and interpreting data; creating explanations; and sharing ideas in the classroom. The teaching of science should not emphasize facts but rather it should focus on student use of evidence for developing and revising explanations of science phenomena. (Krajcik, Czerniak, & Berger. 2003: 4-5). 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: 10-18).

In view of the usefulness of inquiry-based approach to science, many teachers are interested in developing lessons that incorporate real life situations using an inquiry-based approach. In Thailand, inquiry based-teaching is a problem for teachers. It is very difficult to make students deal with inquiry process because they lack science process skills and knowledge of scientific methods. Students without these skills could not conduct their own inquiries. Nowadays, the Institute for the Promotion of Science and Technology (IPST) tries to encourage science teachers to teach science by having students do science research at school. Student would have a chance to use science and technology to solve a problem, learning by their own, and adapt research methods to solve problems in their life. To do science research, students need to learn about inquiry skills that are very important. Furthermore, students would learn what scientists do in order to get scientific facts. The development of activities to enhance students' ability to conduct investigations and develop an understanding of the nature of science inquiry is needed, for doing science is one of the best ways to learn science.

The purpose of this research is to assist students in learning how to conduct a scientific investigation by doing *Brassica rapa* research which could be integrated to promote scientific investigation skills. *B. rapa* is the scientific name of Wisconsin fast plants. Wisconsin fast plants have been useful for teaching biological content such as germination, plant growth and development, life cycle of flowering plants, physiology, ecology, genetics, and evolution. Students were associated with Wisconsin fast plants to work through the inquiry process independently or with a group to develop science learning and to figure out the optimum condition to grow the plants in Thailand.

Rapid Cycling *Brassica rapa*, which belongs to the family *Brassicaceae*, is a type of crucifer, a large group of plants that includes mustard, radish, cabbage. It has been bred for over 30°C at the University of Wisconsin–Madison by Professor Paul H. Williams during 1970s and 1980s. It has short flowering time (14 days) and grows well in a small indoor space, with little soil, under fluorescent light. The plants produce harvestable seeds approximately 40 days after planting. Very specific environmental conditions for growing the plants are required. For example, the range of optimum temperature is 22-26 °C, water must be continuous via capillary wick from a reservoir, and light must be equal to or more than 200 $\mu\text{M PAR, s}^{-1} \text{ m}^{-2}$.

Teachers and students used rapid cycling *B. rapa* in classrooms from kindergarten through college. Learners of all ages can explore a wide variety of questions with rapid cycling *B. rapa* and learn by engaging in genuine scientific inquiry. Learners find the excitement of growing a real, living plant irresistible. Rapid cycling *B. rapa* change visibly each day, right in front of one's eyes. In two weeks, the tiny seeds will germinate, grow, and bloom. In just over a month, students can plant seeds, observe plants, pollinate flowers, and harvest new seeds (Wisconsin fast plants program.2006: online).

The characteristics that make rapid cycling *B. rapa* attractive for teaching purposes are:

- Small size and grows in small space.
- Rapid life cycle, it completes life cycle within 40 days from planting.
- Short flowering time (14 days).
- There are many areas of biology knowledge that can be taught by using rapid cycling *B. rapa*.
- Rapid cycling *B. rapa* changes visibly each day.

- There is a variety of rapid cycling *B. rapa* that can be used for investigating in many areas such as genetics, physiology and environmental studies.
- Rapid cycling *B. rapa* is sensitive to environmental change. Students can easily ask questions and conduct their own experiment to get the answer.

These special characteristics of rapid cycling *B. rapa* that are listed above are useful for introducing this plant to Thailand, a tropical country. High temperatures and humidity are experienced throughout the year. March and May are the hottest months of the year, when even the locals are moved to complain about the heat. From November to the end of February the climate is much less trying with a cooling North East breeze and a reduction in the humidity level. However, rapid cycling *B. rapa* grows well at the range of temperature 22-26 °C which is not normal in Thailand. This means it would be difficult to grow the plants in hot and humid countries such as Thailand.

In this research, students were engaged in Wisconsin fast plants activity. Rapid cycling *B. rapa* is not likely to grow and reproduce easily in Thailand. Before rapid cycling *B. rapa* can be used to effectively enhance students learning in life science in Thailand, the temperature and humidity problems need to be solved. Students were involved to do activities and research in rapid cycling *B. rapa* by conducting their own experiment at final and using inquiry skills in a process of the real research. For the purposes of this study, students who conduct their own experiments not only have the potential to advance their understanding of the nature of science but also integrate their investigation skills and the nature of scientific inquiry which are a necessary experience for success in higher education and in the high-skill to solve problems in everyday life. Moreover, students would understand what/how flower plants life cycle is and many aspects of biology of plants.

2. Objectives of the Study

1. To develop Warm Temperature Adapted Breeding Pool of Wisconsin Fast Plants (Rapid Cycling *Brassica rapa*) as a biological instructional material to promote students' investigation skills.

2. To study students' scientific inquiry skills, understanding of nature of scientific inquiry, understanding of nature of science, and attitude toward science using Warm Temperature Adapted Breeding Pool as a tool.

3. Significance of the Study

This study was divided into two phases. Phase one was to adapt Wisconsin fast plants to warm temperature of Thailand. Rapid cycling *Brassica rapa* of Wisconsin fast plants is a very useful instructional material in biology. It can be used effectively in an inquiry classroom. With its special characteristics: small size and grow in small space, rapid life cycle, short flowering time, change visibly each day and sensitive to environmental change, students can easily ask questions and conduct their own experiment to find the answer. Learners of all ages can explore a wide variety of questions with rapid cycling *B. rapa* and learn by engaging in genuine scientific inquiry. Learners find the excitement of growing a real, living plant irresistible. So, adapting Wisconsin fast plant to warm temperature of Thailand is very useful to Thai classrooms. This study also provides the activity involving Wisconsin fast plants that supports biology classrooms.

Phase two was using Wisconsin fast plant in Thai classrooms. This phase allowed students to experience scientific investigations by doing activity with Rapid Cycling *Brassica rapa* which does not grow well in a tropical area. Students also do research based on real problems using their inquiry and science process skills. Students' inquiry skills: setting testable questions, hypothesis formulation, defining variation, planning to collect and analyze data, drawing conclusion, and communicating results were increased through the activities in this study. These skills are necessary for students to succeed in learning science and understanding the nature of science.

4. Scope of the Study

Population

The population for this study is eighth grade students of Chaturatwittayakarn School located in Chaiyaphum province, Thailand. There were eight classrooms of eighth grade level with 40-45 students in each class.

Sample

The sample of this study is one classroom of eighth grade students. There were 40 students in the class. Sampling technique used in this stage was purposive sampling.

Variables of the study

The variables of this study are as follows:

1. Independent variable:

- Warm Temperature Adapted Breeding Pool (WTABP) of

Wisconsin Fast Plants Activities

2. Dependent variable:

2.1 Students' scientific inquiry skills

- Setting testable questions
- Hypothesis formulation
- Defining variation
- Planning to collect and analyze data
- Drawing conclusion
- Communicating results

2.2 Students' understanding of nature of scientific inquiry

2.3 Students' understanding of nature of science

2.4 Students' attitude toward science

5. Definition of Terms

1. Rapid Cycling *Brassica rapa* means a type of crucifer (a large group of plants that includes mustard, radish, cabbage, and more) that has been bred and selected to have a uniform, short flowering time (14 days) and grows well in a small indoor space, with little soil, under fluorescent lights, and at a temperature of 22-26 °C.

2. A Warm Temperature Adapted Breeding Pool (WTABP) of Wisconsin Fast Plants means Wisconsin fast plant that was adapted to warm temperature. The plants can grow and reproduce seeds in tolerance weather.

3. A Warm Temperature Adapted Breeding Pool of Wisconsin fast plants activities means an activity which is developed based on investigation steps. Students were engaged in asking questions, making predictions, designing investigations, collecting and analyzing data, and communicating the results of the study.

4. Scientific inquiry means a process of learning during which students are engaged in creating their own knowledge and understanding of science, as well as learning how to be scientists. With this pedagogic strategy, students learn science by observing aspects of the natural world, asking questions, making predictions, designing

investigations, collecting and analyzing data, and communicating the results of the study. There are six steps of an investigation in this study:

4.1 Setting testable question means the question that is answered through observation or experiments that provide evidence. It should center on objects, organisms, and events in the natural world and connect to scientific concepts rather than to opinions, feelings, or beliefs. A good testable question leads to gathering evidence and using data to explain how the natural world works.

4.2 Hypothesis formulation is a possible answer, an educated guess, to the question. A useful hypothesis is a testable statement which may include a prediction and leads to an experiment.

4.3 Defining variation means any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled.

4.4 Planning to collect and analyze data is a step for a plan to carry out the experiment step. Students observe, measure, and record data and plan how to analyze data with organization (calculate, construct graphs or make a table of data).

4.5 Drawing conclusion means students use scientific knowledge to make an explanation of an investigation and make a connection between their results and scientific knowledge appropriate at their level of development.

4.6 Communicating is a communication step. Student share the finding using oral presentation. Scientific communication provides students with the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations.

5. Nature of scientific inquiry means the ways science works. The aspects of scientific inquiry are:

5.1 Multiple methods of scientific investigation – scientists used different methods to study their question such as observation and experiment approach.

5.2 Multiple purposes of scientific investigation – scientists have different purpose to study their question depending on their desire, the need of community, or the necessity.

5.3 Justification of scientific knowledge – scientific knowledge need evidence, consistency, and recognition of alternatives to support. Nonetheless, scientists who ask similar questions and follow similar procedures may validly make different

conclusions. Further, scientists who examine the same data may justifiably come to different conclusions.

5.4 Recognition and handling of anomalous data - Recognizing when observations do not fit expectations is a critical part of progress in science. Anomalies spark more questions and drive further investigations.

5.5 Distinctions between data and evidence - Data are observations scientists gather during the course of an Investigation. Evidence is a product of data analysis and interpretation.

5.6 Community of practice - Scientific inquiry is embedded within a community. Practices and standards for developing and accepting scientific knowledge are established within these communities. Communication and peer review impact what and how science progresses.

6. Nature of science means aspects that pertain most to the product of inquiry, the scientific knowledge. It involves a human activity, a process used to investigate natural phenomena, a process used to add to an existing knowledge base, and a social enterprise. Nature of science can be considered to include seven aspects as follows:

6.1 Tentativeness – scientific knowledge is subject to change with new observation and with the reinterpretations of existing observation.

6.2 Empirical basis – scientific knowledge is based on and/or derived from observations of the natural world.

6.3 Subjectivity – science is influenced and driven by the presently accepted scientific theories and laws. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experience dictate what and how scientists conduct their work.

6.4 Creativity and imagination – scientific knowledge is created from human imaginations and logical reasoning based on observation and inference of the natural world.

6.5 Sociocultural embeddedness – science is a human endeavor and is influenced by the society and culture in which it is practiced.

6.6 Observation and Inference – Science is based on both observation and inference.

6.7 Laws and theories – Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Theories and laws do not progress into one another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

7. Students' scientific inquiry skills means students' ability to do science including the skills to set testable questions, making hypothesis, defining variation, planning to collect and analyze data, and drawing conclusion.

8. Students' understanding of the nature of science inquiry means students' ability to understand each aspect of the nature of scientific inquiry.

9. Students' understanding of the nature of science means students' ability to understand each aspect of nature of science.

10. Students' attitude toward science means a person's positive or negative response to the enterprise of science. In addition, it refers specifically to whether a person likes or dislikes science.

6. Conceptual Framework of the Study

The conceptual framework for this study was evolved as a consequence of the literature review in the field of scientific investigation and Rapid cycling *Brassica rapa*. Figure 1 is an attempt to describe relationship between the WTABP of Wisconsin Fast Plant Investigation Activity and scientific inquiry skills, understanding of nature of scientific inquiry, understanding of nature of science, and attitudes towards science.

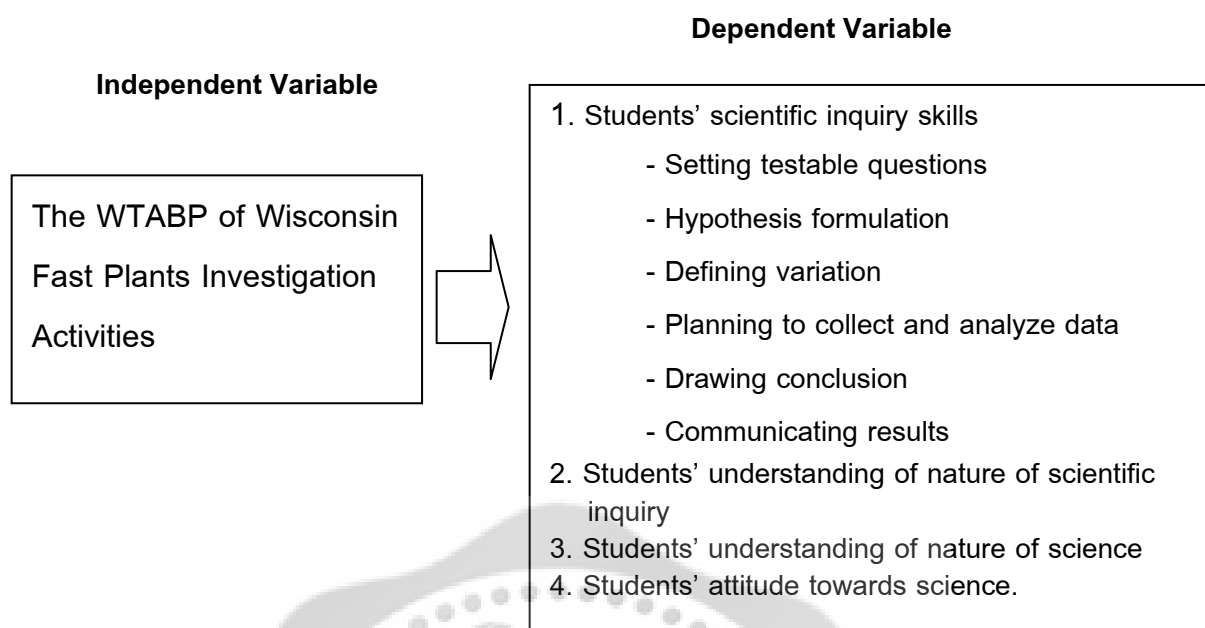


FIGURE 1 CONCEPTUAL FRAMEWORK OF THE STUDY

7. Research Hypothesis

1. Students' scientific inquiry skills mean score was higher than the cutting score of scientific inquiry test.
2. Students' understanding of nature of scientific inquiry mean score was higher than the cutting score of nature of scientific inquiry test.
3. Students' understanding of nature of science mean score was higher than the cutting score of nature of science test.
4. Students' attitude toward science was at a high level.

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter begins with the detail of constructivism followed by inquiry-based instruction and its feature and processes, scientific investigation, Wisconsin fast plants (Rapid Cycling *Brassica rapa*), and previous research on scientific inquiry.

Constructivism

During the last half of the 20th century, Piaget's work on intellectual development has provided educators with a foundation for constructivism. For example, from the major implications of his views for educational practice: (1) young child is quite different from adult in several ways, (2) children have to act on things in order to learn, (3) children are most interested and learn best when experience is moderately novel, and (4) children should have the opportunity to talk with one another in school – to argue and debate, these are emphasized on constructivist approach (Piaget, Ginsburg and Oppen: 1979). Educators can derive from some of his view which guide educational procedures in a view of constructivist idea. A constructivist classroom, then, consists of learner centered, active instruction. Constructivism in Piagetian thought is concerned with the ways that the construction of new knowledge by the learner is influenced by prior knowledge. Constructivist teaching approaches focus on a learner's prior knowledge and efforts to consider new way of thinking about phenomena and event, for it is the learner who must do the work of integrating new ideas into his or her thinking (Shapiro: 1994: 37-50). Shapiro also presented the features of a constructivist view of knowledge in science teaching as: (1) reality, (2) knowledge, (3) the purpose of knowing, (4) the role of learner, and (5) the role of the teacher.

Shapiro (1994:37-50) states that *reality* does not exist separately from the observer. There are many forms of reality, each depending on the observer's frame of reference and interaction with the observed. *Knowledge* not only consists of facts, principles, and theories deduced from observations of phenomena and events but also includes the ability to use information in meaningful ways. *The purpose of knowing* is not to discover reality but to adapt knowledge from experience. *The role of the learner* is not to passively receive information, but to actively participate in the construction of new ideas. And, *the role of the teacher* is not to simply present new information, correct students' misconceptions, and

demonstrate skills but to guide the learner to consider new ways of thinking about phenomena and events.

Constructivist Model of Learning

Constructivism is the idea that learners build their own knowledge and their own representation of knowledge from their own experience and thoughts. Learning is not the result of teaching; it is the result of what students do with the new information they are presented with. In other words, students are active learners who construct their own knowledge.

Mayer (2007) proposes that in constructing new knowledge, learners select specific aspects of incoming information to consider, organize the selected information in various ways such as by sequencing, classifying, connecting, and relating to form new conceptual knowledge. The process of selection, organization, and integration of information are automatic, but they become more effective as children learn to monitor and regulate their own learning and as they build up a bank of knowledge and experiences.

Students' prior knowledge is very important for them as the basis for constructing new knowledge. They come to class with experience that they have been picked up from all sorts of events, places, people in their lives and the media. Sewell (2002: 24-28) identifies the four different ways students deal with new information that differs from their previous understanding or knowledge.

1. Delete the preexisting knowledge
2. Modify the preexisting knowledge so that it fits the new information
3. Modify the new information so that it fits the old knowledge
4. Reject the new information

The students' prior knowledge influences what new or modified knowledge they will construct as a result of their learning experience in the classroom. Teaching based on constructivist theory must take into consideration the prior knowledge of students because preexisting knowledge can be as a barrier to learning.

Kelly (1991) proposed in his personal construct theory that experience is crucial to students' learning. Students look at the world through mental constructs or patterns which they create. They develop ways of constructing or understanding based on their experience. When they encounter a new experience, they attempt to fit these patterns over the new experiences.

In addition, Shiland (1999: 107-108) stated that knowledge is constructed in the mind of the learner. He further explained this statement as follows:

1. Learning requires mental activity. The process of knowledge construction requires mental effort or activity; material cannot simply be presented to the learner and learned in a meaningful way.
2. Naïve theories affect learning. New knowledge must be related to knowledge the learner already knows. The learner has preconceptions and misconceptions which may interfere with the ability to learn new material. These personal theories also affect what the learner observes.
3. Learning occurs from dissatisfaction with present knowledge. For meaningful learning to occur, experience must be provided that creates dissatisfaction with one's present conceptions. If predictions about an experience's present conception make an accurate prediction about an experience, restructuring will not occur.
4. Learning has a social component. Knowledge construction is primarily a social process in which meaning is constructed in the context of dialogue with others. Cognitive growth results from social interaction. Learning is aided by conversation that seeks and clarifies the ideas of learner.
5. Learning needs application. Applications must be provided which demonstrate the utility of the new conception.

Shiland postulates that teachers must design suitable activities and instructional materials to encourage students to construct their own knowledge. For example, in his first statement - *learning requires mental activity*, teachers should modify activities to increase the cognitive thinking of learners. In other words, teachers make students dissatisfied with their present knowledge then, challenge them to solve the problem related to that dissatisfied knowledge on their own. Students can construct their own knowledge by getting through real problems.

Constructivist Classroom

A constructivist classroom is a student-centered classroom (Gray. 2007: online). Science must be taught by teachers who can guide student thinking by pointing out to students what they need to focus on in the activity, and who know when to give students explanations for phenomena (Chiappetta; & Koballa. 2002: 51-78). In constructivist classrooms, the environment is democratic, the activities are interactive and student

centered, and the students are empowered by a teacher who operates as a facilitator/consultant. Students are engaged in constructivist activities, such as small group, hands-on activities. They are also immersed in experiences within which they may engage in meaning-making inquiry, action, imagination, invention, interaction, hypothesizing and personal reflection in order to build their own knowledge. Gray (2007: online) and Matthews (2003: 51-64) suggested that constructivist teachers are able to flexibly and creatively incorporate ongoing experiences in the classroom into the negotiation and construction of lessons with small groups and individuals. Teachers need to recognize how students use their own experience, prior knowledge and perceptions, as well as their physical and interpersonal environments to construct knowledge and meaning. Furthermore, in a constructivist classroom, teachers and students share responsibility and decision making and demonstrate mutual respect. The learning relationship is mutually beneficial to both students and teachers.

Chiappetta and Koballa. (2002: 51-59) indicated that constructivist science teaching might view the learning process as a journey that begins where students reside. The voyage is a collaborative effort between the learner and teacher. The students mark the starting point based upon what they believe and know. The direction for each trip is charted by the ideas students wish to test as well as the territory the teacher has selected for study. In some instance, opportunities are provided for students to stop along the way to interact with objects and observe events. In other instances, there are teachers, adults, and peers who share their ideas of the world and keep students moving. Since students cannot discover all of the important ideas on their own, social interaction is necessary. Students benefit from discussions with teacher and peers who can help them to acquire new concepts. Students with different skills and backgrounds should collaborate in tasks and discussions in order to arrive at a shared understanding of the truth in a specific field.

Inquiry - Based Instruction

The National Science Education Standards of the United States note:

inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (p. 23)

Developing the ability to understand and engage in this kind of activity requires direct experience and continued practice with the processes of inquiry (National Research Council: 2000: 1-74). Moreover, teaching science focuses on active learning and de-emphasizes the memorization of technical vocabulary, facts, laws, and theories. Cain (2002) also stated that in inquiry-based science, learners construct knowledge by being involved in science experiences in which they frame a question and design and carry out an investigation that will provide data to answer the question. Schwab (1962: 3-103) argued that science should be viewed as conceptual structures that were revised as the result of new evidence. From his idea, it follows that teachers should present science as inquiry and students should use inquiry to learn science subject matter.

The Feature of Inquiry-Based Instruction

The Inquiry in the National Science Education Standards (National Research Council, 2000: 24-29) identified five essential features that characterize classroom inquiry below:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicated and justify their proposed explanations.

1. Learners are engaged by scientifically oriented questions.

Inquiry in the classroom should begin with authentic questions generated by students from their own experience. Students learn how to ask good questions from teachers. The teacher plays a critical role in guiding the identification of questions, particularly when they come from students.

2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

In inquiry classroom, students use evidence to develop explanations from scientific phenomena. They use a variety of investigational approaches to gather evidence,

including descriptive, classificatory, and experimental investigations. They also gather information from articles, textbooks, encyclopedias, databases, the Internet, and so on, placing an emphasis on understanding the natural world rather than acquiring terminology and fact (Carin, Bass, and Contant. 2005: 71-92).

3. Learners formulate explanations from evidence to address scientifically oriented questions.

Scientific explanations are based on reason and evidence. They must be consistent with experimental and observational evidence about nature. They respect rules of evidence, are open to criticism, and require the use of various cognitive processes generally associated with science. Continuing in inquiry, students describe, classify, and explain their observations, and clarify and justify their work to themselves and to one another. As they develop cognitive skills, students should learn to distinguish between explanations, which are ideas about why something happens and descriptions, which are based on observations of what has happened.

4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

An essential component of this characteristic is ensuring that students make the connection between their results and scientific knowledge appropriate to their level of development. That is, student explanation should ultimately be consistent with currently accepted scientific knowledge.

5. Learners communicated and justify their proposed explanations.

Scientific communication requires clear articulation of the question, procedure, evidence, proposed explanation, and review of alternative explanation. It provides further skeptical review and the opportunity for others to use the explanation to work on new questions. Having students share their explanations provides others with the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations.

Five essential features of inquiry are based on a model of what scientists do in the real world. Inquiry-based teaching can also vary in the amount of detailed guidance that the teacher provides. The Inquiry in the National Science Education Standards of the United States (2000: 29) identified the inquiry variations as shown in Table 1.

TABLE 1 ESSENTIAL FEATURES OF CLASSROOM INQUIRY AND THEIR VARIATIONS
(NATIONAL RESEARCH COUNCIL, 2000, P.29)

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

As shown in the table, inquiry variations described in the amount of structure, guidance, and coaching the teacher provides for students engaged in inquiry, broken out for each of the five essential features. It could be said that most open form of inquiry-based teaching and learning occurs when students' experiences are described by the left-hand column in the table (National Research Council: 2000: 29).

The Level of Inquiry

Banchi and Bell (2008) described scientific inquiry in four levels: confirmation, structured inquiry, guided inquiry, and open inquiry. The details are below.

1. Confirmation

At this level, students are provided with the question and procedure (method), and the results are known in advance. Confirmation inquiry is useful when a teacher's goal is to reinforce a previously introduced idea; to introduce students to the experience of conducting investigations; or to have students practice a specific inquiry skill, such as collecting and recording data.

2. Structured inquiry

At this level, the question and procedure are still provided by the teacher. However, students generate an explanation supported by the evidence they have collected.

3. Guided inquiry

At this level, the teacher provides students with only the research question, and Students design the procedure (method) to test their question and the resulting explanations. Because this kind of inquiry is more involved than structured inquiry, it is most successful when students have had numerous opportunities to learn and practice different ways to plan experiments and record data.

4. Open inquiry

At this level, students have the purest opportunities to act like scientists, deriving questions, designing and carrying out investigations, and communicating their results. This level requires the most scientific reasoning and greatest cognitive demand from students. This includes being able to record and analyze data, as well as draw conclusions from the evidence they have collected.

The Nature of Scientific Inquiry

American Association for the Advancement of Science (AAAS) (1993: 1-8) identified the nature of science as having three principle aspects: scientific world view, scientific inquiry, and scientific enterprise. First, Scientific world view means the world is understandable, scientific ideas can change, scientific knowledge is long-lasting, science cannot provide complete answers to all questions. Second, the scientific enterprise describes that science is a complex social activity, science is organized into content disciplines and is conducted in various institutions, ethical principles govern the conduct of science, and scientists participate in public affairs both as specialists and as citizens. The third, scientific inquiry means science demands evidence, science blends logic and

imagination, science explains and predicts, scientists try to identify and avoid bias, and science is not authoritarian. This topic will be focused on the nature of scientific inquiry.

As mentioned above, scientific inquiry is described as having many aspects. AAAS (1990: 1-8) and Chiappetta and Koballa. (2002:113-132) state that science demands evidence. The heart of science is the requirement of evidence. They indicated that questions are the beginning of science understanding. Scientific questions lead to investigations that produce data that can be used as evidence for answering the questions. To have a valid scientific claim, phenomena have to be observed carefully in order to collect accurate data. Carin, Bass, and Contant (2005: 74-91) further stated that scientists use the evidence of investigations to answer their questions. They arrive at (1) descriptions of objects, organisms, and events; (2) classification that suggest which properties might be most significant; (3) inferences, predictions, and relationships; and (4) explanations of how and why things work. Science explains and predicts (AAAS.1990: 1-8). Scientists try to make sense of observation of phenomena by constructing explanations. The explanation must relate to a significant body of scientifically valid observation, and must show relationships among phenomena. Carin, Bass and Contant (2005: 74-91) stated that the essence of science is validation of claims by observational evidence. Explanation requires prior knowledge of concepts and principles. Explanation must be logically sound, must be consistent with currently accepted scientific principles, and must incorporate valid observations. Explanation should not only fit available observations, but they should also lead to predictions about additional observations not yet made. They further stated that scientist are not satisfied with mere observations but they look for underlying patterns, seek hidden meanings, and propose explanations for their observations. Scientific ideas must have predictive power (AAAS. 1990: 1-8), AAAS. 1993: 3-21), Chiappetta;& Koballa. 2002). It is not enough for scientific theories to fit only the observations that are already known. The predictive power of a theory predict not only the events in the future but also evidence from the past that has not yet been found or studied.

Darden (1998: online) and Carin, Bass, and Contant (2005: 79-101) pointed out that scientific inquiry is dynamic and continually changing. Scientific ideas are based on the experimental and observational confirmation so that all scientific knowledge will be changed when new evidence becomes available (National Research Council. 1996: 11-24). Scientific knowledge is never fixed nor complete, and always subject to revision with new evidence. Darden (1998: online) further pointed out that scientific inquiry is an ongoing process of

error correcting – constructing plausible hypotheses, generating as many plausible rivals as possible, designing new experiments, correcting errors in hypotheses in the face of anomalies. Science thrives on open and free debate about the merits of rival hypotheses. Scientists publish hypotheses that may later be disproved by new evidence and replaced by a better rival. Carin, Bass, and Contant (2005: 79-101) suggest that student should come to understand that no matter how well and widely accepted theory fits observations, a new theory might fit them as well or better. Further scientific work served to correct the mistakes.

Scientists believe in principles of logical reasoning that connect evidence and assumptions with conclusions. To support the logical principle in science, scientists must conduct a good experiment so that they have reasonable evidence (AAAS. 1990: 1-8). Further, the inquiry process does not stop with empirical data. The logic and reasoning used to explain laws and theories are also critical to scientific understanding. Ideas are not merely stated. They must be explained to elucidate the mechanisms involved. Moreover, ideas and explanations generated through investigations must be scrutinized for bias – the personal thinking that leads to faulty data. However, science has limitations (AAAS. 1993: 3-21). It cannot provide humankind with all of the answers about all aspects of reality, such as morality and religious belief. Science is only one way in which human seek understanding and answers to their questions.

Schwartz and her colleagues (2008. 4-6) distinguish nature of scientific inquiry into seven aspects

1. Scientific questions guide investigations. Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world. Contrary to the common “step one” of the scientific method, all investigations do not begin with the statement of a hypothesis. Before hypothesizing or considering what information may be helpful to gain understanding, scientists must ask questions.

2. Multiple methods of scientific investigations. Scientists use different kinds of Investigations depending on the questions they are trying to answer. There is no single “scientific method” that all scientists follow to produce valid knowledge. Studies of scientists in practice demonstrate that investigative approaches vary in form. An experimental approach involves hypothesis testing through identifying and controlling variables of importance to the question, and manipulating one variable at a time to determine resultant

effects. Experimental investigations are most similar to “the scientific method” that persists in textbooks and on classroom posters. Another type of approach does not involve manipulation of variables, either because manipulation is not possible or is not desirable to answer the question of interest. This approach involving observations of natural phenomena and void of direct disturbance by the observer can result in valid scientific understanding of the phenomena. Questions guide all these approaches. However, scientists may follow different procedures to address the same question.

3. Multiple purposes of scientific investigations. In general, scientists aim to build and revise theoretical models with unobservable mechanisms. The questions scientists choose to pursue stem from many sources and can serve many purposes. Why scientists choose to investigate certain questions may relate to curiosity, social impact, economy, practicality, or any variety of other reasons. “Current scientific knowledge and understanding guide scientific investigations.” The work of scientists may help solve a socially-based situation (such as disease), may be necessary to develop desired technology, may improve human condition, or may advance basic understanding of our world.

4. Justification of scientific knowledge. Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The processes of negotiating meaning and gaining consensus involve building justification for claims. Evidence, consistency, and recognition of alternatives are associated elements. Nonetheless, scientists who ask similar questions and follow similar procedures may validly make different conclusions. Further, scientists who examine the same data may justifiably come to different conclusions.

5. Recognition and handling of anomalous data. Investigations are guided by current knowledge and theory, thus scientists have expectations. Recognizing when observations do not fit expectations is a critical part of progress in science. Anomalies spark more questions and drive further investigations. Authentic science involves a variety of approaches to handling anomalous information. These include rejection (error negates anomaly), ignoring the anomaly, inclusion without explanation, abeyance (set aside), acceptance with theory change, reinterpretation of data, peripheral theory change.

6. Distinctions between data and evidence. Data and evidence serve different purposes and come from different sources. Data are observations scientists gather during the course of an investigation. They can take a variety of forms (e.g. numbers, descriptions,

photographs, audio, physical samples, etc). Evidence is a product of data analysis and interpretation.

7. Community of practice. Scientists review and ask questions about the results of others' work. Science advances through logical skepticism. Scientific inquiry is embedded within a community. There are multiple communities within the broader community of science. Practices and standards for developing and accepting scientific knowledge are established within these communities. Communication and peer review impact what and how science progresses.

TABLE 2 THE NATURE OF SCIENCE ASPECTS

Aspects	Description
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical basis	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.

TABLE 2 (continued)

Aspects	Description
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Sociocultural embeddedness	Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.
Observation and inference	Science is based on both observation and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.

TABLE 2 (continued)

Aspects	Description
Laws and theories	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.
Interdependence of these aspects	None of these aspects can be considered apart from the others. For example, tentativeness of scientific knowledge stems from the creation of that knowledge through empirical observation and inference. Each of these acts is influenced by the culture and society in which the science is practiced as well as by the theoretical framework and personal subjectivity of the scientist. As new data are considered and existing data reconsidered, inferences (again made within a particular context) may lead to changes in existing scientific knowledge.

Science Investigation

Hackling (2005: 2-24) stated that model of science investigation processes encompasses four steps: planning, conducting, processing, and evaluating (Figure 2)

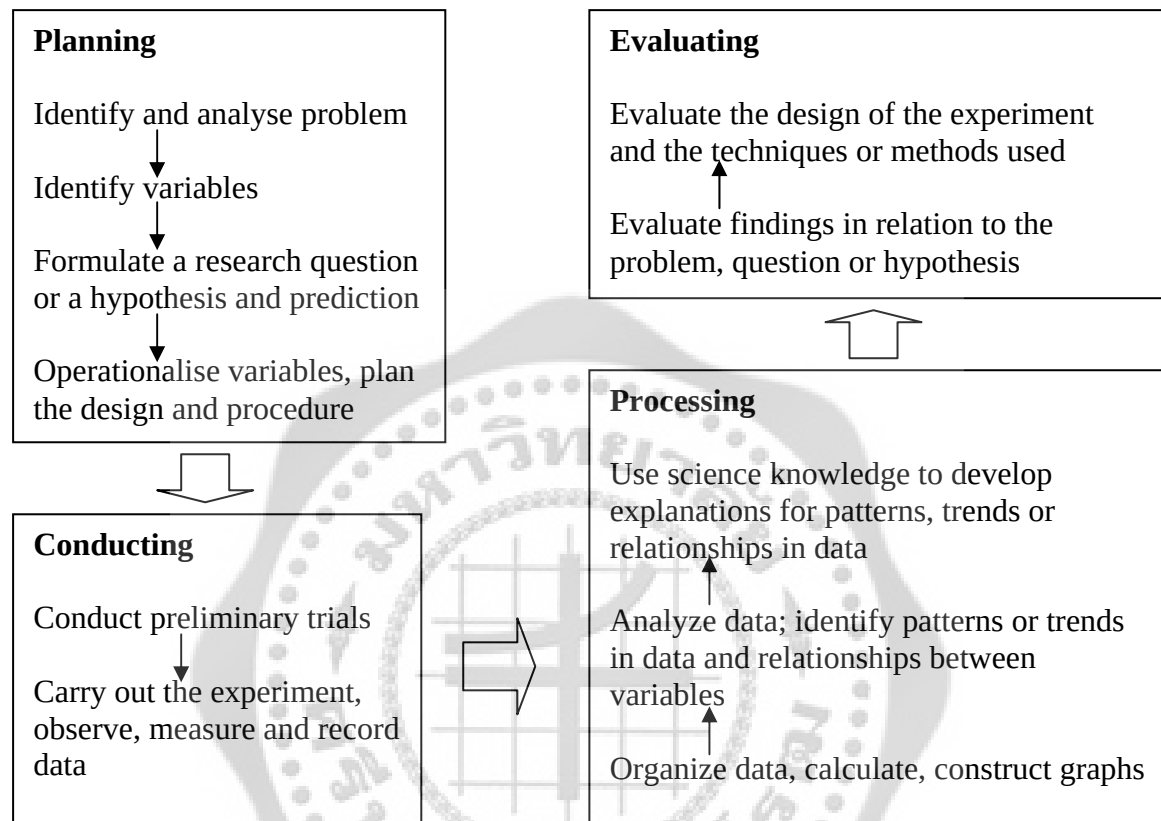


FIGURE 2 A MODEL OF SCIENCE INVESTIGATION PROCESSES (Hackling, 2005: 4)

Source: Mark W. Hackling. (2005). Working Scientifically: Implementing and Assessing Open Investigation Work in Science. p. 4

He also indicated that the process of the investigation may not take place in the strict order of, say, Planning – Conducting – Processing – Evaluating, because halfway through Conducting it may be realized that more planning is needed.

Investigation Web

Krajcik, Czerniak, and Berger (2003: 117-164) indicated that scientific investigation is a nonlinear process so that they have proposed investigation web as a process of carrying out and investigation that includes “messing about,” asking and refining questions, finding information, planning and designing, building the apparatus and collecting data, analyzing data, making conclusions, and communicating finding. Each component of an investigation provides feedback for another part (Figure 3).

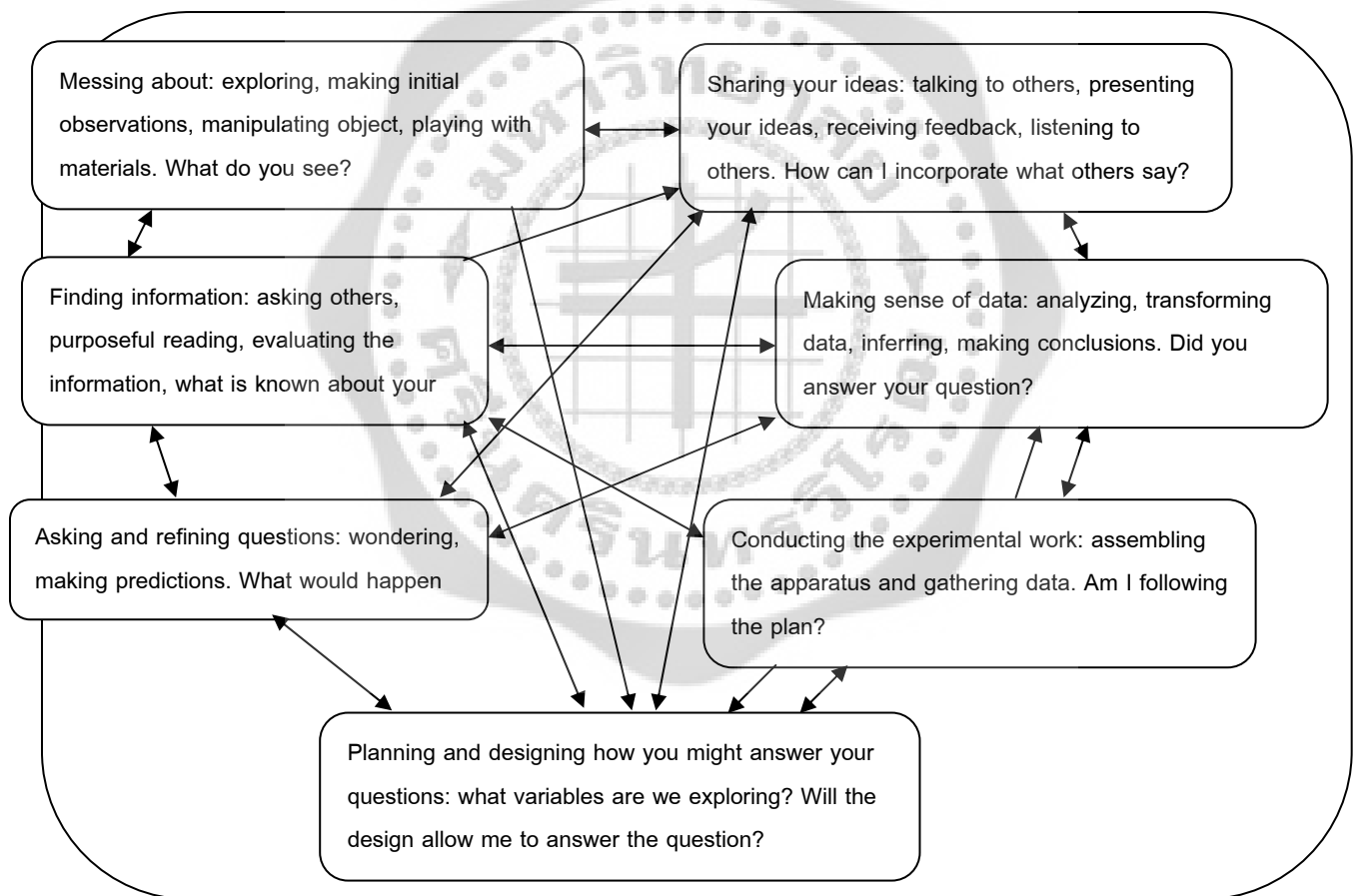


FIGURE 3 THE INVESTIGATION WEB

Source: Krajcik, Czerniak, and Berger. (2003). Teaching Science in Elementary and Middle School Classroom: A Project-Based Approach. p.119.

From the National Research Council, Hackling, and Krajcik, Czerniak, and Berger statement, researchers decided to separate the process of scientific investigation into steps: setting testable question, hypothesis formulation, defining the variable, planning to collect and analyze data, making results, drawing conclusion, and communicating results.

Conducting Scientific Investigation

Inquiry in elementary school and middle school is usually thought of in terms of three kinds of investigations: Descriptive, Classificatory, and Explanatory (National Research Council, 1996, p. 123). Carin and Bass (2001: 123-167) further elaborate on these types of investigations. First, descriptive investigations are often used in elementary school because students are usually encouraged to explore and interpret objects, materials, and phenomena. Questions leading to descriptive investigations are often “what” questions. Observation is important for this kind of investigation. Second, classificatory investigations involve searching for productive ways of grouping objects or organism according to their properties or traits. Students’ natural curiosity motivates them to explore the world by observing, comparing and contrasting, and sorting and classifying simple objects in their environment. And third, explanatory investigations; in this kind of investigations, students collect information and combine it in ways that help make sense of natural phenomena. Students often ask “why” questions that are not testable. But many of their questions can be revised to how and why questions that can be answered. Posing questions, collecting information through observing, and linking evidence with developing knowledge to explain what students see are needed. Explanatory investigation is for upper elementary and middle grades.

There is more than one way to investigate the natural world. Bentley, Ebert, and Ebert (2000: 201-217) classify eight types of investigations which are trial and error, documenting, prediction testing, product testing, experimenting, reflecting, generating models, and inventing. These are the ways scientists investigate phenomena. The outcomes of these investigations probably are product, information, or question/guide for future pursuit depending on what type of investigation. However, teachers who established an investigation approach to teach science should not focus on product but the process of the investigation is the primary concern.

At grades 6 to 8, Benchmarks (AAAS. 1993: 3-21) states that students can be expected to become more sophisticated at conducting inquiry. By this level, they should be familiar with the different aspects of investigation and be able to design and conduct long-term experimental investigations in which one specific variable is manipulated while other variables are controlled (Cain, 2002: 33). Engaging students in doing realistic investigations provides a foundation for developing scientific literacy, enables them to continue to grow and develop in their ability to

explore new phenomena, compare different theories, engage in making scientific predictions, and make sense out of the unfinished and tentative nature of science (Ebenezer and Connor, 1998: 47-63).

Zorfass (1998: 54-62) stated that to carry out active research is not a one time experience. The active researcher does not engage in inquiry for a prescribed period of time and then stop. Instead, a search for knowledge raises new questions and identifies other areas to explore. Teaching science to children by engaging them to do the investigation should be continuous process. From one experiment, they are engaged to do another one. Students need time to investigate scientific questions, collect and apply evidence, and communicate the outcomes of their investigations. These processes can contribute to students' understanding of science concepts and how science knowledge has been developed over time. They also should have opportunities to work as small groups to conduct investigations, evaluate evidence, and formulate explanations.

Assessment of Inquiry

Assessment that is appropriate for student doing science investigation has many different labels: active assessment, direct assessment, performance assessment, alternative assessment, and many others. Krajcik, Czerniak, and Berger (2003: 313-332) stated that assessing students' inquiry skills should focus on authentic assessment. It is an assessment that most closely measures what happens during instruction and inform instruction are more genuine and justifiable. They reported that assessment appropriate for science classrooms has the following features:

1. It is responsive to context. Teachers who use assessment to plan, monitor, and improve teaching are reflective practitioners.
2. It is a continuous process embedded in instruction. Assessment is embedded in instruction and is difficult to distinguish from instruction.
3. It is multidimensional. Effective teachers use many different assessment techniques.
4. It engages students in the assessment process. Assessment engages students in the process to help them become reflective learners who regulate their own learning.
5. It is valid and reliable. Assessment should consistently and accurately measure students' learning.
6. It matches today's educational goals. Teacher today are trying to monitor knowledge, skills, and attitudes relevant to out-of-school life.
7. It accommodates cultural diversity. Assessment techniques need to pay attention to meeting the needs of diverse students.

8. It is consistent with learning theory. Assessment techniques are consistent with how children learn.

9. It measures meaningful understanding. Assessment should measure meaningful understanding rather than focusing on single, correct answers.

In the context of inquiry, assessments need to gauge the progress of students in achieving the three major learning outcomes of inquiry-based science teaching: conceptual understanding of science, abilities to perform scientific inquiry, and understanding about inquiry (National Research Council. 2000: 27). Teachers in inquiry classrooms use a variety of assessment techniques embedded in instruction to continuously monitor growth in individual students' knowledge, skills, and attitude and to help plan instruction accordingly.

Abruscato (2004: 99-120) proposed that in assessing inquiry there are four steps in the process and the final product should be evaluated: indentifying a worthwhile and researchable questions, planning the investigation, executing the research plan, and drafting the research report. He suggested in his book that to assess students' understanding of science and inquiry process, teachers have to use different assessment approaches: traditional assessment techniques such as quizzes, reports, authentic assessment such as the use of portfolio, science conference, concept mapping, and journals.

Inquiry is the agent of constructivist teaching. Many educators suggest that teacher should use an authentic assessment associated with traditional assessment to measure students' investigation skills. There are several authentic methods of assessing process skills and inquiry as follows:

Rubrics

Rubrics provide a scoring system that is particularly useful during assessment. They give teachers a way to classify students' work into achievement levels, or levels of performance. Instead of using words such as outstanding, excellent, fair, average, poor, better than or worse than, descriptors of performance explain qualitatively how one level of performance differs from another. Accompanying the qualitative description is a scale, which assigns the points a student will gain for this or her performance. Scales vary along a continuum of quality, with numbers ranging from 0 and 1 at the low end, to 2, 3, and 4 at the mid range, and 5 or 6 at the high end. The higher the score, the better the performance. There are two different types of rubrics: holistic rubrics and analytic rubrics. Holistic rubric is used to looks at the performance as a whole. If teachers want to provide a student with an overall picture of his or her performance, they would use a holistic rubric. Analytic rubric is used to examine the component parts of the performances. If teachers want to identify a particular

aspect (or aspects) of performance and provide feedback on just that aspect, they would use an analytic rubric.

Performance Tasks

Performance tasks are science problems that students attempt to solve by applying their knowledge, process, and skills. Students respond in writing, or sometimes by building something and evaluating how well it answers the problem. Students' proficiency in content understanding, skills, and processes is judged by rating student responses against scoring keys or rubrics.

Educational Assessments

In order to determine the effectiveness of Rapid cycling *Brassica rapa* activity, the norm-referenced test and criterion-referenced test must be applied in the context of the study. Below are details of norm-referenced test and criterion-referenced test.

Norm-Referenced Tests

A norm-referenced test is a test that compares a student's test performance with that of similar students who have taken the same test. A score on a norm-referenced test is intended to describe a student's test performance in relation to others who took the test at the same time or to others whose scores are used to establish external criteria for performance levels (Hopkins and Antes. 1985:329). After a test has been constructed, the test developers administer it to a standardization sample of students using the same administration and scoring procedures for all students. This makes the administration and scoring "standardized". The test score of the standardization sample are then converted to norms, which include a variety of types of score. Once a norm-referenced test has been standardized, it can be administered to students with characteristics that are similar to the norm group and the scores of these students can be compared with those of the norm group (Cohen; & Spenciner. 2003: 55-57). Norm-referencing employs the practice of comparing a student's performance to the performance of the class as a whole, or in the case of a standardized test, to some external population or norm group. The trait or ability measured is assumed to be present in varying degrees among students and the test is designed to ascertain the level relative to other students. Students' scores are placed in order from high to low and the arithmetical average and the variability (a measure of the dispersion of scores) determined. With this information relative positions of scores are determined. Further interpretation of student performance is made by the teacher as

he or she reflects on performance of the individual and class in relation to performance of previous classes at this level for this particular subject matter (Hopkins and Antes. 1985: 329)

Norm-referencing for classroom tests is used widely when educational objectives are based on the cognitive domain, but also serves the higher levels of the affective and psychomotor domain. However, norm-referencing provides little information about the degree of proficiency of performance in absolute terms (Hopkins and Antes. 1985: 329).

Criterion-Referenced Tests

Criterion-referencing describes each examinee's test performance in terms of specific behaviors. The test is used to ascertain a student's status with respect to a well-defined domain of knowledge and behavior (Hopkins and Antes. 1985: 329). While norm-referenced tests are constructed to discriminate between the performances of individual students on specific test items, criterion-referenced tests provide a description of a student's knowledge, skills, or behavior in specific range of test items. This specific range is referred to as a domain. Test items on criterion-referenced tests are frequently tied to well-defined instructional objectives. Criterion-referenced tests, instead of using norms, provide information on the performance of a student with respect to specific test items. The results of criterion-referenced tests are not dependent on the performance of other students, as are norm-referenced tests.

Distinguishing Norm-Referenced Test from Criterion-Referenced Test

There are several characteristics that distinguish norm-referenced tests from criterion-referenced tests. First is mastery. Performance on a criterion-referenced test provides information on whether the student has attained a predetermined level of mastery. Performance can be interpreted as mastery, nonmastery, or intermediate. Second is the breadth of the content domain covered by the test. Typical norm-referenced tests survey a broad domain, while criterion-referenced tests usually have fewer domains but more items in each domain. Third, criterion-referenced tests can also be very useful in helping to make instructional planning decisions. Since criterion-referenced tests frequently cover a more restricted range of content than norm-referenced tests, they can provide more information about a student's level of performance (Cohen; & Spenciner.2003) There are more detail of the similarity and difference between norm-referenced test and criterion-referenced tests as shown below.

TABLE 3 SIMILARITIES AND DIFFERENCES BETWEEN NORM-REFERENCED AND CRITERION-REFERENCED TEST.

Norm-referenced tests	Criterion-referenced tests
Purposes: to examine individual performance in relation to a representative group; can be used to establish age levels; used for diagnosis and placement.	Purposes: to examine individual performance in relation to a criterion or external standard; cannot be used to establish age levels unless normed; used for program planning and evaluation because items are sensitive to effects of instruction (intervention).
Test construction: items usually not developed from task analysis; test items may or may not be related to the objectives of instruction (intervention).	Test construction: items developed from task analysis; test items are related to the objectives of instruction (intervention).
Administration: must be administered in a standard manner	Administration: may or may not be administered in a standard manner.
Scoring: based on standards relative to a group; variability of score (mean, standard deviations) is desired with normal distribution.	Scoring: based on absolute standards; variability of scores is not obtained because perfect or near-perfect scores are desired.
Psychometric properties: test should demonstrate reliability and validity.	Psychometric properties: test should demonstrate reliability and validity.

Source: Montgomery P.C. & Connolly B.H. (1987: 1874). *Norm-Referenced and Criterion-Referenced Tests: Use in Pediatrics and Application to Task Analysis of Motor Skill*. USA.

Cut-off Score

The cut-off score was used in this study as the standard point for criterion evaluation. The students who have test score at this point or more than this point are classified as a master of learning objectives. In this study, the cut-off score was used as the criterion-referenced measurement for students' scientific inquiry skills scores, students' understanding of nature of scientific inquiry scores, and students' understanding of nature of science scores. The process of establishing cut-off score follows Berk (1976. 4-9). The details are as follows:

1. Two criterion groups are selected: instructed and uninstructed. The instructed group should consist of those students who have received "effective" instruction on the objective to be assessed. The students who had studied with Rapid cycling *Brassica rapa* activity in the field trial study were defined as the instructed group, while the students who had not studied with the Rapid cycling *B. rapa* activity yet in the main study were defined as the uninstructed group.

2. Collecting data of students' score from students' post-test in the pilot study as the instructed group scores, and students' pre-test score in the main study as the uninstructed group scores.

3. Constructing the distribution graph. The instructed and uninstructed group score distributions are the primary determinants of the tests whether or not they can classify students as true masters and true nonmasters of an objective. If the distribution is completely overlapped, it indicates that the test cannot classify students. If there is no overlap, it indicates that the test can classify students with perfect accuracy. The point at which the distributions intersect is the optimal cutting score (figure 5). The predictor and criterion classification of students according to their test score results in four possible outcomes as indicated in the figure 4 below:

True Masters (TM)	False Masters (FM) Type II misclassification
False Nonmasters (FN) (Type I misclassification)	True Nonmasters (TN)

FIGURE 4 THE CRITERION CLASIFICATION OF STUDENTS

- True Masters (TM): the instructed students who have scores at or above the cut-off score
- False Masters (FM): the uninstructed students who have scores at or above the cut-off score (Type II misclassification)
- True Nonmasters (TN): the uninstructed students who have score below the cut-off score
- False Nonmasters (FN): the instructed students who have score below the cut-off score (Type I misclassification)

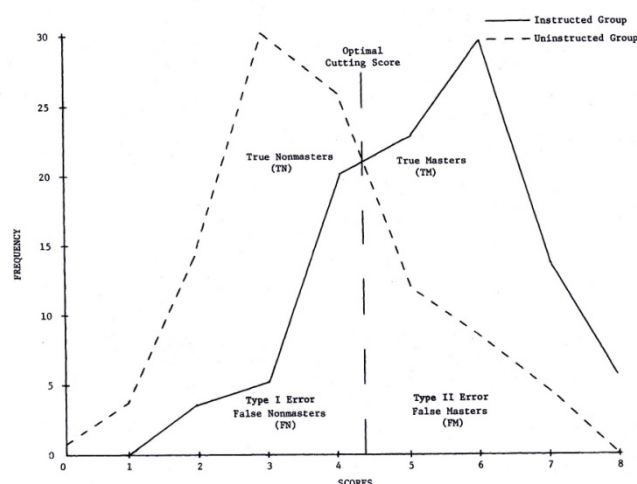


FIGURE 5 SCORE DISTRIBUTION GRAPH

Source: Berk, A.R. (1976, Winter) Determination of optional scores in criterion-referenced measurement. *Journal of Experimental Education*, 45(2): 4-9.

4. Calculating the probability of every outcome, the probability of correct decisions, the probability of incorrect decisions and validity coefficient for each score. The following formulas in Table 4 can be used in the calculation.

5. Determining the cutting score from the score which maximizes the probability of correct decisions, and minimize the probability of incorrect decisions. The cut-off score can also be the score which maximizes the validity coefficient.

TABLE 4 FORMULAS FOR THE PROBABILITY CALCULATION

	Formulas for the calculation
The probability of every outcomes	$p(TM) = TM/(M+N)$ $p(FM) = FM/(M+N)$ $p(TN) = TN/(M+N)$ $p(FN) = FN/(M+N)$
The probability of master	$BR = p(FN) + p(TM)$
The probability of predicted master in the population	$SR = p(TM) + p(FM)$
The probability of correct decisions	The probability of correct decisions = $p(TM) + p(FM)$
The probability of incorrect decisions	The probability of incorrect decisions = $p(FN) + p(TN)$
The validity coefficient	

Source: Wichaidit, S. (2010: 53). A Development of Plant Biology Learning Units Incorporated with an Analogy Technique for Lower Secondary School Students. Dissertation, SWU.

Rapid Cycling *Brassica rapa*

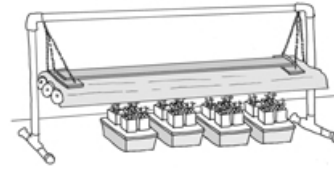
Rapid Cycling *Brassica rapa*, which belong to the family *Brassicaceae*, are a type of crucifer which is a large group of plants that includes mustard, radish, cabbage. It has been bred by Williams and colleagues in the Department of Plant Pathology at the University of Wisconsin-Madison during the 1970s and 1980s for use as a biological educational and research tool (Hill and Williams, 1986: unpagged). Within the genus *Brassica* are six related species: *B. nigra*, *B. juncea*, *B. carinata*, *B. oleracea*, *B. napus*, and *B. rapa*. Rapid Cycling *Brassica rapa*, a derivative from wild *B. rapa*, illustrates the power of artificial selection by plant breeders. It is often used to communicate the effectiveness of selection to students beginning their work with rapid cycling *B. rapa* (Goldman, 1998). Williams developed the rapid cycling *B. rapa* through a process of recurrent selection for early and concentrated flowering, short stature, ability to grow under continuous fluorescent lighting, absence of seed dormancy, and ability to grow at high density (Hill and Williams, 1986: unpagged). Since their introduction, rapid cycling *B. rapa* have been adopted by thousands of primary and secondary schools throughout the world for use in teaching biological principle such as plant growth and development, life cycle of flowering plants, physiology, ecology, genetic, and evolution. In addition, rapid cycling *B. rapa* have a short life cycle (35-40 days); hence, the plants served a useful role in demonstrating advanced genetic and evolution concepts.

Rapid Cycling *Brassica rapa* and Its Environments

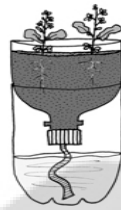
Williams (2008: online) suggests how to grow RBR in his “Sandbox” at the Fast Plants website (www.fastplants.org). The ideal conditions for growing rapid cycling *B. rapa* involve physical, chemical, and biotic environment control. The physical environment consists of temperature (22-26°C), light ($200\mu\text{M PAR}, \text{s}^{-1} \text{m}^{-2}$, 24 hrs a day), gravity (keep plants growing vertically), space ($4\text{cm}^2/\text{plant}$), and soil volume (15 cc/plant). For the chemical environment, rapid cycling *B. rapa* need water that is supplied continuously via capillary wick from a water reservoir, nutrients at the level appropriate for the plant that you desire nutritional states (starving, hungry, well fed, and over fed). The plants also need air ($\text{RH} > 70$) for growing. The biotic environment in the form of competition with other plants, insects, microbes: algae, fungi, bacteria, and viruses can also affect the growth of rapid cycling *B. rapa*. These aspects of the environment need to be controlled during plant growth. There are three growing systems of rapid cycling *B. rapa* from Williams’s Sandbox (figure 6) as follows:



Light Box System



Light Bank System



Bottle Growing System

FIGURE 6 THE GROWING SYSTEMS OF RAPID CYCLING *Brassica rapa*

Source: Wisconsin Fast Plants Program.(2008). Introduction to Fast Plants and How to Grow. (Online)

Rapid Cycling *Brassica rapa* as Educational Models

General and advanced university courses in botany, biology course in secondary and high school usually lack suitable living plant materials that permit students to explore plant growth development, physiology, reproduction, genetics, evolution and ecology. Rapid cycling *Brassica rapa* are particularly amenable to the classroom setting because they show rapid development. The plants flower in 14-18 days under cool temperature (22-26 °C). They are small, and they can reproduce at high densities (up to 2500 plants per square meter) under fluorescent lighting in a classroom.

Williams and colleagues (Williams; et al. 2004: 1-6) publicized using rapid cycling *B. rapa* as an inquiry tool in a book called *Spiraling Through Life with Fast Plants: an inquiry-rich manual*. The book contains many of inquiry activities including areas on germination, growth and development, flowering, pollination, and fertilization to seeds. The book has been very effective in promoting classroom inquiry around the world. Baker and Piburn's work is a good example of using RBR to develop students' inquiry skill. (Baker and Piburn. 1997). They used RBR to encourage students to develop a hypothesis and apply the scientific method in a field setting by having students work through the experiment in pairs. They reported that students

had an opportunity to set the hypothesis, collect their data, write individual scientific reports, and present their finding in class.

Goldman (1998: unpagged) chose rapid cycling *Brassica rapa* in his plant breeding course because of its life cycle compared to other plants. He developed a model system using *B. rapa* for teaching the cyclical selection process known as recurrent selection in the context of a course on plant breeding. The system allows for up to three cycles of recurrent selection during a single 15-week semester and enables students to gain experience in planting, selection, pollination, and seed harvest during each cycle. By repeating this process two or three times during the semester, students also gain valuable experience with the crucial aspects of recurrent selection. Using the rapid cycling *B. rapa* model, recurrent selection can be practiced successfully by students in the classroom (Goldman: 1998: unpagged).

Past Research about Students' Ability to Conduct Investigation

O'Neill and Polman (2004: abstract) make a strong case for a practice-based scientific literacy, arguing through three related empirical studies taking the notion of "little scientists" seriously might be more productive in achieving current standards for science literacy than continuing to refine ideas and techniques based on the coverage of conceptual content. They reported the results of three studies. Study 1 is a classroom case study that illustrates how project-based instruction can be carried out when teachers develop guidance and support strategies to bootstrap student's participation in forms of inquiry they are still in the process of mastering. Study 2 shows how sustained on-line work with volunteer scientists appears to influence students' success in formulating credible scientific arguments in written project reports following an authentic genre. Study 3 uses data from three suburban high school classes and suggests that involving students in the formulation of research questions and data analysis strategies results in better spontaneous use of empirical data collection and analysis strategies on a transfer task. Their work also suggests that struggling (and even failing) to formulate and carry out empirical investigations in science may teach students more meaningful lessons about how science is accomplished than flawlessly executing cookbook labs or solving carefully formulated problems.

Erdogan (2006: 3-7) reported that students learn science as inquiry and the nature of science as expressed in the National Science Education Standards by constructing hands-on models of natural wastewater treatment and wastewater treatment facilities to achieve an understanding of wastewater treatment process in nature and wastewater treatment facilities. Students have the opportunity to experience a long-term experiment and to develop the skills

and understanding of scientific inquiry. They become strong, assertive, and independent learners by exercising their ability to apply what they learned in scientific investigation.

Thompson (2007: 27-33) engaged student learning plant function by using guided inquiry approach. He has students observe plant in a jar both in quantitative and qualitative observation before sealing the jar. For quantitative observation, students focus on number of leaves on the plant, the number of healthy, dead, or dying leaves, plant height, plant width, number of flowers, and temperature inside the jar. For qualitative observation, students focus on description of the plant, soil, and jar. After sealing the jar, he asked student to write a detailed description of what they think is going to happen to the plant and why in their science journal. From the result, students understand more about plants function and better understand the history and nature of the work of scientists engaged in inquiry and nature of scientific work.

Case and Miller (1999: 42-45), known as the Kansas Collaborative Research Network (KanCRN) works with researchers, teachers, and students interested in conducting research and have created an open, Internet-based community. KanCRN helps students become active researchers, collaborate with others, and use the skills of scientific inquiry. One of their research studies is developing student-scientist research partnerships using tardigrade biodiversity. Students participate in the tardigrade project by getting the opportunity to expand the known distribution, diversities, and habitats of many species of the arthropod. Either individually or as a class, students can calculate the diversity and density of various types of tardigrades found in lichen. KanCRN project want students to understand science by conducting their own research by encouraging students to publish their work on an online database on the KanCRN website to share data with other school and community. The tardigrade research helps create a rich context of understanding in which students develop their own research questions and inquiry skills.

The Partnership for Research and Education in Plants (PREP) (2004) brings science teachers, students, scientists, and outreach personnel to collaborate in sharing knowledge and research about plant molecular genetics and general plants biology. The PREP program support teacher and students as they design and conduct experiments in wild-type and mutant *Arabidopsis thaliana* to examine functions of different genes during plants growth and development. From this project, students, working in pair or small groups, have an opportunity to conduct their own real experiments, collect real data, analyze, draw conclusions, and share real data. Student share their findings with their peers, their community, and research scientists in plant biology at a year-end conference and on PREP website. According to student conducting their own experiments, students not only have the potential to advance their own

understanding of the nature of science, scientific inquiry, but are also with appropriate guidance, providing a wealth of reliable, accurate data that can be used for further study of biology (PREP, 2004, p. 2).

To conduct realistic investigation, students are encouraged to post their own question, design and conduct the investigation by introducing them to real problems. However, Pieters, Limbach and Jong (2004) reported that students have substantial problems with the inquiry processes. Students have difficulty choosing the right variables to work with; they find it difficult to state testable hypotheses, and they do not necessarily draw the correct conclusion from experimental data and hypotheses, because their pre-existing ideas tend to persist even when they are confronted with data that contradict those ideas. Students also struggle with basic experimental processes. It is difficult for them to translate the variables from their hypothesis into observable variables in the experiment. Students always vary too many variables at one time, fail to make predictions, and make mistakes when interpreting data.

In this research, students had done the scientific inquiry which is the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Scientific inquiry reflects how scientists come to understand the natural world, and it is at the heart of how students learn. Scientific inquiry is also a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions.

The previous research indicated that having student conduct scientific inquiry could make them learn the way scientists seek for their questions and improve scientific inquiry skills,

In this research, students had a chance to:

- 1) Learn how to identify and ask appropriate questions that can be answered through scientific investigations.
- 2) Design and conduct investigations to collect evidence needed to answer a variety of questions.
- 3) Use appropriate equipment and tools to interpret and analyze data.
- 4) Learn how to draw conclusions and think critically and logically to create explanations based on their evidence.

- 5) Communicate and defend their results to their peers and others.

Developing students' investigation skill by using Rapid Cycling *Brassica rapa* provides students with Wisconsin fast plant activities and real scientific investigation (Activity 4). Because Rapid cycling *Brassica rapa* do not grow well in high temperature, change visibly in every single days, and are sensitive to environment, students could easily observe and see what they want to study and then design and conduct investigations to solve their problem by themselves. By doing an investigation, students had an opportunity to learn how to do scientific inquiry from the beginning to the end with the special characteristic of Rapid cycling *Brassica rapa* activities. They should improve their scientific inquiry skills, understanding of nature of scientific inquiry, understanding of nature of science, and their attitude towards science should be improved by the end of this research.



CHAPTER 3

RESEARCH METHODOLOGY

This study consisted of two phases. The first phase was to develop Warm Temperature Adapted Breeding Pool (WTABP) of Rapid Cycling *Brassica rapa* as a biological instructional material to enhance students' investigation skills and their understanding of the nature of scientific inquiry. The second phase was to study students' ability to conduct scientific inquiry, understand the nature of scientific inquiry, and understand the nature of science using Warm Temperature Adapted Breeding Pool as a tool.

The study began with the first phase: development of biological instructional material and research tools for gathering data. Warm Temperature Adapted Breeding Pool of rapid cycling of *Brassica rapa* was developed. Three steps of studying Wisconsin fast plants aspects, development of rapid cycling *B. rapa* adapted to warm temperature, and growing Warm Temperature Adapted Breeding Pool (WTABP) were performed. WTABP activities and research tools for gathering data were distributed followed by the second phase. This phase consisted of a description on community and school context, participants, data gathering, and data analysis procedure.

Phase One: Development of Biological Instructional Materials

This phase involved three main parts. The first is development of warm temperature adapted breeding pool (WTABP) of Rapid cycling *Brassica rapa*. Second is a preliminary study on students' involvement in realistic investigation. Third is development of warm temperature adapted breeding pool (WTABP) classroom activity and research tools for gathering data. The development of Warm Temperature Adapted Breeding Pool (WTABP) of rapid cycling *B. rapa* describes experiment design and conducting the experiments. The preliminary study on students' involvement in realistic investigation describes how students learn to do scientific inquiry and instruments to observe their behavior through the research. Development of warm temperature adapted breeding pool (WTABP) classroom activity involved four inquiry activities. The WTABP activity and research tools for gathering data consist of three sub-parts that are: 1) development of WTABP classroom activities and 2) conducting field trial of activities and 3) revising the activities.

1. Development of Warm Temperature Adapted Breeding Pool (WTABP) of

Rapid cycling *Brassica rapa*

There are two steps in this section: 1) Studying rapid cycling *B. rapa*. aspects
2) Development of rapid cycling *B. rapa* adapted to warm temperature.

Before designing the experiments, all aspects and information of Wisconsin fast plants were studied. A standard Stock 1-33 was used in this study. The experimental design was separated into two steps as follows:

1.1 Studying Rapid cycling *Brassica rapa* aspects

All aspects of Wisconsin fast plants including growth, development, and reproduction were explored.

1.2 Development of Rapid cycling *Brassica rapa* adapted to Warm Temperature

This step consists of growing many successive generations of rapid cycling *B. rapa* in warm temperature to allow the plants adapt themselves to ambient temperature in Thailand and to produce a lot of seeds.

Conducting the Experiments

1.1 Studying Rapid cycling *Brassica rapa* aspects

Rapid cycling *Brassica rapa* were experimentally grown in various conditions. Growth, development, and reproduction were studied. Cotyledon width and height were measured. Numbers of leave and flower were counted. Anther, pollens and embryogenesis were studied under the microscope. Seed pods and germination were also observed. Life cycles of the plants under various conditions were investigated.

1.3 Development of Rapid Cycling *Brassica rapa* Adapted to Warm

Temperature

Rapid cycling *Brassica rapa* were grown in various conditions in order to allow the plants to adapt to warm temperature.

Experiment 1: Temperature Shifting 1

Materials

1) A lighting bank system - A lighting bank system most appropriate for growing large numbers of plants. The light bank uses only 60 cm × 150 cm of space, which accommodates several large classroom experiments. The light bank consists of 6 or more 4 foot fluorescent bulbs side by side. The most common bulb used is a 40-watt cool white (Wisconsin fast plants program.2012: online).

- 2) A growing system - growing system in this experiment was a quad with 12-celled planting units
- 3) Potting mix - potting mix contains peat and vermiculite
- 4) Fertilizer - fertilizer contains equal amount of nitrogen, phosphorus, and potassium.
- 5) Seeds stock 1-33

Experimental Design

Seeds were sown in 140 pots with four seeds in each pot. The pots were separated into two groups: group 1 and group 2 with 70 pots in each group. Each group composed of 10 subgroups, which contained 7 pots in each subgroup. Both of group 1 and 2 were put into 35 °C. In group one, the first subgroups were moved from 35°C to 32 °C on day 4, and the rest of the subgroups were moved consecutively. For example, the second subgroup was moved on day 5. The third subgroup was moved on day 6 and finally, the tenth subgroup was moved on day 13 (Figure 7). The plants were grown at 32°C until open flower were obtained (day 14) and pollination was performed on days 15 to 18. One pot in each subgroup was moved back to 35 °C every two days after pollination (range from days 20 to 32). The plants in group two were treated the same as that of group one but the plants were moved from 35 °C to 28 °C instead. The seeded gained from this experiments was considered the Generation 1.

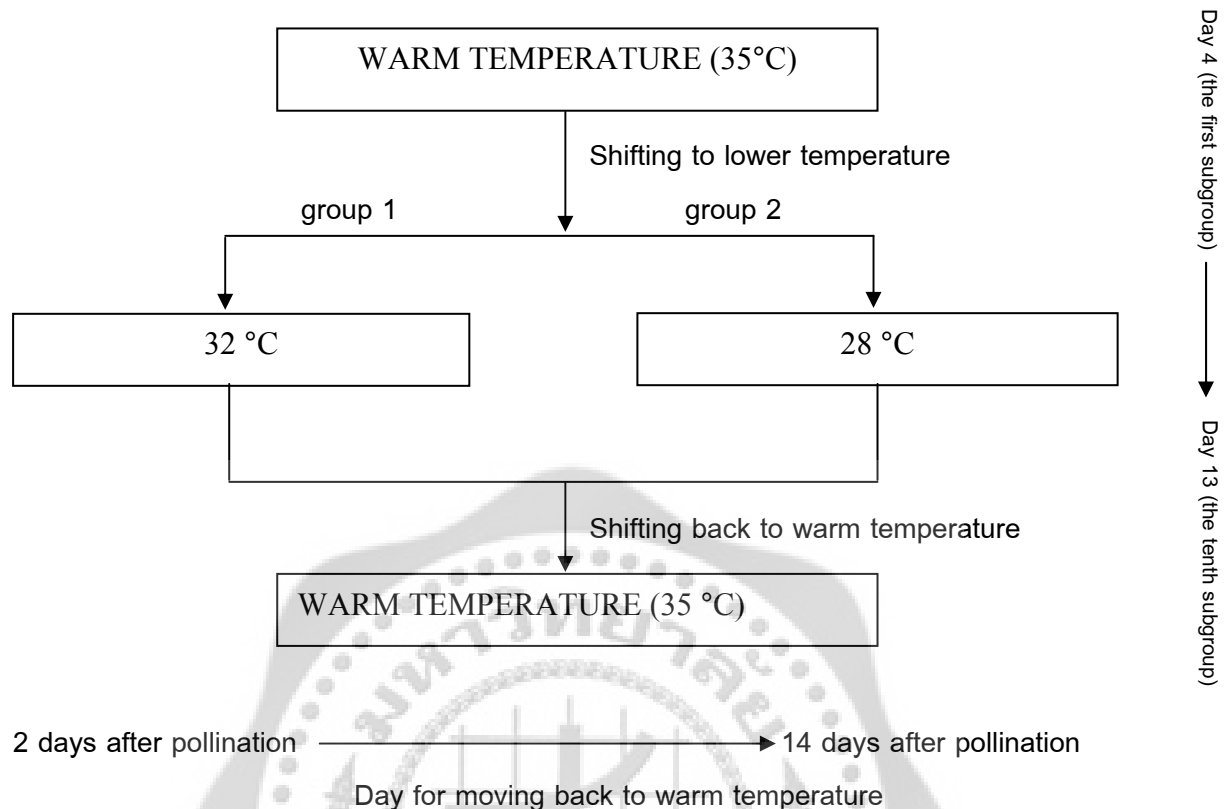


FIGURE 7 TEMPERATURE SHIFTING 1

Experiment 2: Temperature Shifting 2

Materials

Materials used in this experiment was the same as those in the experiment 1 but Seeds stock 1-33 (Generation 1)

Experimental Design

Seeds from experiment 1 were selected to sow in experiment 2. The purpose of this experiment is to select the seeds that demonstrate the shortest time on developing reproductive organ at warm temperature. Seeds were sown in 30 pots with four seeds in each pot and water was supplied via capillary wick. The pots were separated into two groups: group 1 and group 2 with 15 pots in each group. Each group composed of 5 subgroups, which contained 3 pots in each subgroup. Both of group 1 and 2 were put into 35°C. In group one, the first subgroups were moved from 35 °C to 32 °C on day 7, and the rest of the subgroup were moved consecutively. For example, the second subgroup was moved on day 8. The third subgroup was moved on day 9 and so on. Finally, the fifth

subgroup was moved on day 11 (Figure 8). The plants were grown at 32 °C until open flower were obtained (day 14) and pollination were performed on days 15 to 18. One pot in each subgroup was moved back to 35 °C every two days after pollination (range from days 20 to 24). The plants in group two were treated the same as that of group one but the plants were moved from 35 °C to 28 °C instead. During the reproductive organs are developed, the plants were observed very closely. The seeds gained from this experiment were considered the Generation 2.

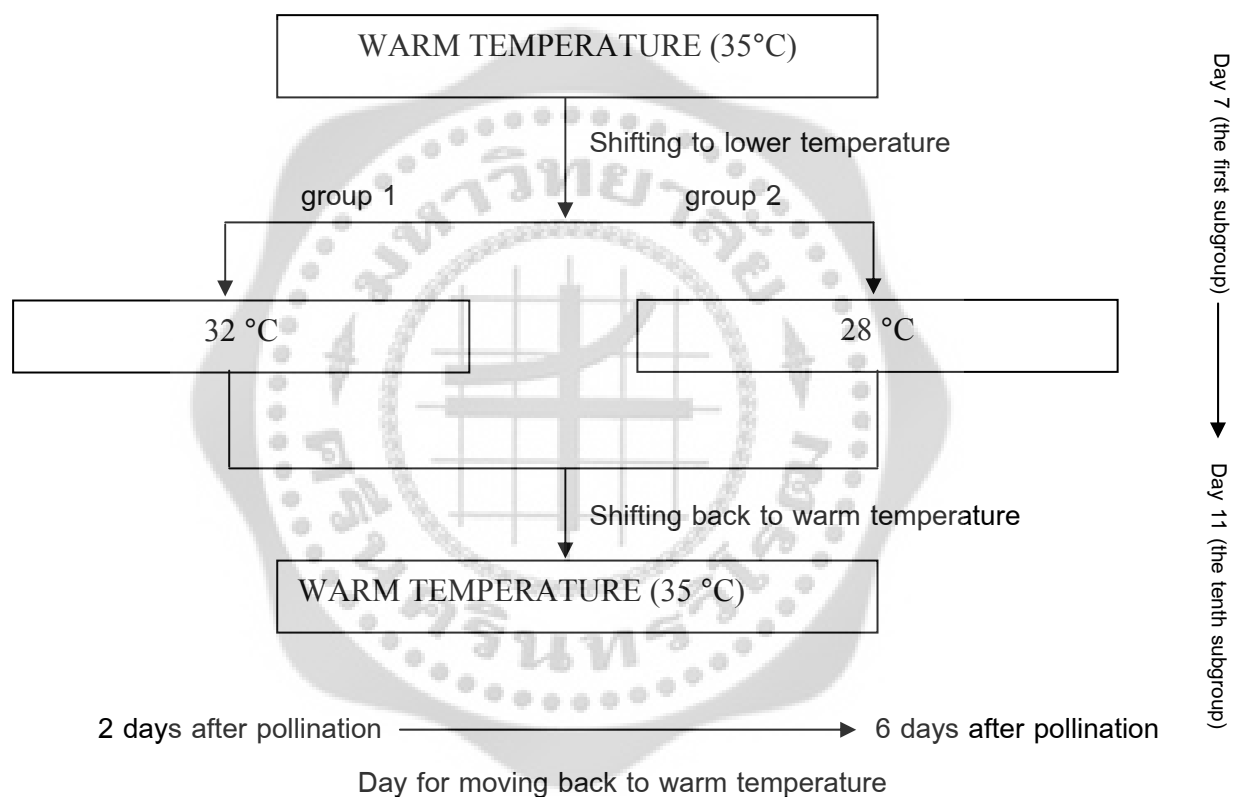


FIGURE 8 TEMPERATURE SHIFTING 2

Experiment 3: Ventilation System

Materials

Materials used in this experiment were the same as those in the experiment 1 but Seeds stock 1-33 (Generation 2). Ventilation system (fan) was associated when the temperature of the growing system was higher than 35 °C.

Experimental Design

Seeds from experiment 2 were selected to sow in experiment 3. This experiment was performed in ambient temperature, about 35 °C at day time and 28 °C at night time. Fertilizer was added at days 0 (sowing day), 7, and 14. The plants were carefully observed during reproduction time (days 7 to 18). Ventilation system (fan) was used during reproductive organ development in order to control the temperature about 33°C. The seeds gained from this experiment were considered the Generation 3.

Experiment 4: Ambient Temperature (22-35 °C)

Materials

Materials used in this experiment were the same as those in the experiment 1 but Seeds stock 1-33 (Generation 3).

Experimental Design

Seeds from experiment 3 were selected to sow in experiment 4. This experiment was done in ambient temperature. Fertilizer was added at days 0 (sowing day), 7, and 14. The plants were carefully observed during reproduction time (days 7 to 18). Seeds were counted and recorded.

Preliminary Results

According to the experimental design, the main purpose of the study was to produce Warm Temperature Adapted Breeding Pool of Wisconsin Fast plants. A standard stock 1-33 was used throughout this study. The results demonstrated that Wisconsin fast plants could develop and reproduce in warm temperature under various conditions (Figure 9). The number of viable seeds was higher in late generation. Seed's appearance was evident as both round and flat shape. The color of the seed is lighter than that of the original seed obtained from Science House at UW – Madison. The range of optimum temperature for warm temperature-adapted Wisconsin Fast plants is 22 – 35 °C.

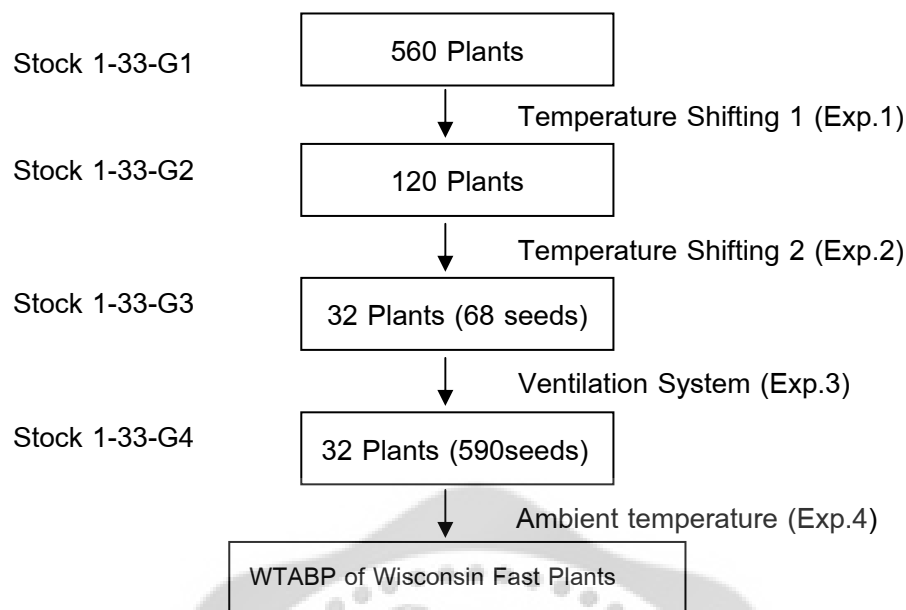


FIGURE 9 SCHEMATIC FOR DEVELOPING WTABPOF WISCONSIN FAST PLANTS

Preliminary study on students' involvement in an investigation

This part intended to study students' involvement in an investigation. The result of this part was used as the preliminary information for developing activity used in classroom. The details of the participants and the research instruments used in this part are as follows:

1.1 Participants

Participants involved in the investigation were three eight grade students. They volunteered to participate in this research. They were 13-14 years old and studied at Kumuangwiththaya School. Their parents were farmers growing crops such as sugar cane, cassava, corn, and vegetables. They always help their parents in the farm so they are familiar with plants enough to grow and observe Rapid Cycling *Brassica rapa*. There are four experiments in Development of Warm Temperature Adapted Breeding Pool (WTABP) of Rapid cycling *B. rapa* - experiment 1: temperature shifting 1, experiment 2: temperature shifting 2, experiment 3: Ventilation systems, and experiment 4: ambient temperature. These three students involved in only experiment 3 and 4. Students were provided with information on the warm-temperature-adapted Rapid cycling *Brassica rapa* from experiments 1 and 2 which took place at the University of Wisconsin–Madison. They involved in asking, making hypothesis, growing, observing, measuring, collecting data (leave

number, height, cotyledon width, flower number etc.) of the plants, and making and communicating a result.

1.2 Research Instrument

To study students' investigative skills and understanding of nature of science, View of Scientific Inquiry Questionnaire (VOSI (S)) was developed by Lederman N.G. and his colleague in 2002. The purpose of the questionnaire is to study students' understanding of nature of science. The instrument was translated and adapted for use with Thai students. The questionnaire consists of seven questions concerning nature of scientific inquiry. Students were to express their idea after they had done the activity. The observation form was developed to observe students' investigative skills. Students' investigative skills were based on their behavior throughout the research and laboratory notebooks. The semi-structured interview form was developed for students' knowledge of flowering plant. They were also asked to write their prior knowledge of the life cycle of flowering plants before and after conducting the research. The researcher gave them a chance to investigate Rapid cycling *Brassica rapa*. Their behavior and how they performed the experiment were closely observed by the researcher.

2. The Development of Warm Temperature Adapted Breeding Pool (WTABP)

Classroom Activity and Research tool for gathering data

2.1 Development of Warm Temperature Adapted Breeding Pool

(WTABP) Classroom Activity

This part aims to allow students to learn how to do an investigation. Students were engaged in an inquiry process by using WTABP. The investigation activities were developed based on usefulness of WTABP of rapid cycling of *Brassica rapa*. The activity began with students asking testable questions, planning, conducting, processing, evaluating, and reporting result. There are four investigation activities as follows:

1. Seed size and growth of fast plants
2. Temperature and pollen shape
3. Light and development of fast plants pods
4. Scientific inquiry activity

For each of the activities, the validity structure, appropriateness, and the suitability of time allocation of the activity were evaluated by experts: educators, science teachers, and scientists. The experts' suggestions were used for improving the activity.

Then, the activities were tried out in a nontarget science classroom. Each activity was revised before implementing with the participants. Followed by students doing realistic investigation, students conducted their own investigation based on the problem of growing rapid cycling of *Brassica rapa* in warm temperature. They formulated a research question, designed an experiment, collected and analyzed data, and communicated their finding with peers. Most of the time of this activity was devoted to discussion in classroom and sharing of the data that students got from their experimental observation. Students presented their result to class at the end of the activity. The activities were evaluated by experts. The experts' suggestions were considered when revising the activities. The activities were piloted with nontarget students and were revised before implementing with participants.

2.2 Conducting a Field Trial

The purpose of conducting a field trial is to test the quality of the Warm Temperature Adapted Breeding Pool (WTABP) Classroom Activity before implementing to participants. In addition, conducting a field trial also helped reveal the problems that could happen during the use of the activities.

All Warm Temperature Adapted Breeding Pool (WTABP) Classroom Activities were conducted as a field trial to non-participants. One classroom of eighth-grade students was selected. They were taught by the researcher.

2.3 Revising the Activities

Revision of the component of the activities is obviously a way to determine where changing might be made in order to improve the activities. The activities were used with the participants.

2.4 Construction of the Research Tools for Gathering Data

The research tools used in gathering data consist of:

- 1) The scientific inquiry skills test
- 2) The nature of scientific inquiry test
- 3) The nature of science test
- 4) The science attitude scale for middle school students

The detailed description of the construction of the research tools is provided below.

1) Constructing the scientific inquiry skills test

The scientific inquiry skill test consisted of four items in writing open-ended format which allowed student to express their own idea in writing. This test was the tool for evaluating five aspects of students' scientific inquiry skills. The process of test constructing was as follows:

Step 1: reviewing related literature concerning scientific inquiry skills which consisted of setting testable question, formulating hypothesis, planning to collect and analyze data, drawing conclusion, and communicating results.

Step 2: constructing the scientific inquiry skills test based on the four activities of rapid cycling of *Brassica rapa*. The test consisted of 12 open-ended items.

Step 3: Examining content validity of the test. The test was examined by the experts in terms of the Item Objective Congruence (IOC). After all items had been examined by three experts, all items gained the index value more than 0.67. Therefore, these items were revised according to the experts' comment.

Step 4: testing the quality of the test items. The test was tried out with 30 middle school students who had studied science project course. Students' scores from this examination were analyzed to gain item difficulty index (p-value) and item discrimination (r) for each item (Osterlind. 1998: 266). After the test has been tried out, items difficulty index ranked from 0.59 to 0.74, and item discrimination ranked from 0.21 to 0.32. More details about items difficulty index and item discrimination were presented in the appendix B.

Step 5: examining the reliability of test score. Thirty middle school students who had done science project course took the test. Students' score from this examination were analyzed using Cronbach' s coefficient alpha (α). The reliability of test score was 0.80.

For the last aspects of scientific inquiry skills, scientific communication was evaluated after the activity. The mean score of students' scientific communication was evaluated compared to the criteria score (Srisa-ard. 1992). The four category scores were as follows:

- The mean score 3.51-4.00 interpreted as the highest level
- The mean score 2.51-3.50 interpreted as the high level
- The mean score 1.51-2.50 interpreted as the medium level
- The mean score 1.00-1.50 interpreted as the low level

2) Constructing the nature of scientific inquiry test

View of Scientific Inquiry questionnaire (VOSI Questionnaire) was used to assess students' understanding of nature of scientific inquiry. The test was developed by Schwartz, Lederman, and Lederman in 2008. The test were translated into Thai and used in the main study.

There are two key factors that are important to this instrument. The first factor is the reliability, that is, whether the test score is accurate, precise, consistent and reproducible. The VOSI Questionnaire has a reliability coefficient of 0.74. The second factor to consider is validity, that is, whether the test measures what you actually want to measure. Strong confirmations of this instruments validity come from the results of a project conducted by Schwartz S., Lederman N.G., & Lederman J.S. Schwartz is a science educator at the Western Michigan University. Lederman N.G. and Lederman J.S. are science educators at Illinois Institute of Technology (Schwartz, Lederman, & Lederman. 2008). The result was that the VOSI is indeed valid as a measure of an ability to understand the nature of scientific inquiry.

3) Constructing nature of science test

View of Nature of Science Elementary/middle school version (VNOS-D) was used to assess students' understanding of nature of science. The questionnaire was developed by Lederman and his colleague in 2002 (Lederman, N.G.; et al. 2002). The test were translated into Thai and used in the main study.

There are two key factors that are important to this instrument. The first factor is the reliability, that is, whether the test score is accurate, precise, consistent and reproducible. The VOSI Questionnaire has a reliability coefficient of 0.83. The second factor to consider is validity, that is, whether the test measures what you actually want to measure. Strong confirmations of this instruments validity come from the results of a research conducted by, Lederman N.G., Schwartz S., Abd-El-Khalick F., and Bell R.L.(Lederman, N.G.; et al. 2002.). The result was that the VNOS-D is indeed valid as a measure of an ability to understand the nature of science.

4) Constructing the Science attitude scale for middle school students

The science attitude scale for middle school students (SASMSS) was developed by Frank L. Misiti, Robert L. Shrigley, and Lylee Hanson in 1991. There are 23

statements to assess students' attitudes toward science that are divided into five subcomponents of the attitude object as follows (Misiti; & Shrigely; & Hanson. 1991):

The mean score of students' attitude towards science was evaluated compared to the criteria score (Tanaprayothsak. 2005: 58). The five category scores were as follows:

- The mean score 4.51-5.00 interpreted as the highest level
- The mean score 3.51-4.50 interpreted as the high level
- The mean score 2.51-3.50 interpreted as the medium level
- The mean score 1.51-2.50 interpreted as the low level
- The mean score 1.00-1.50 interpreted as the lowest level

The SASMSS has passed several tests suggesting some degree of validity. For the internal consistency, the coefficient alphas for the 23 items on the two set of data were 0.96 and 0.92, respectively. Before use, the SASMSS 22 was selected because of its appropriateness to Thai students. The coefficient alphas for the 22 items are 0.86, strongly suggesting that the items are interconnected.

Phase Two: The Research on Students' Ability to Conduct Scientific Inquiry, Understand of Nature of Scientific Inquiry, and Nature of science

This section consists of four sub-sections: community and school context, participants, data gathering, and data analysis procedure.

1. Community and school context

The school is located in Chatturat district, Chaiyaphum, Thailand. It serves students from more than 15 villages in the district area. Most students are from poor farming communities. Many members of the communities grow sugar cane, corn, and rice. The school is a grade 7 through grade 12 school, with a total of 38 classes in the school. The school time is from 7:45 am to 3:30 pm. There are approximately 1,560 students with approximately 35-40 students in each class. Students in grade 7 through 9 must study two science courses in each semester. One is core science for 3 hours a week while the second is an elective science course for 2 hours a week.

2. Participants

The participants in this study were eighth grade students. Students in this level were 13-14 years old. During the semester, they took two science courses consisting of one core science course and one elective science course. For the elective course, they gained experience by doing simple scientific investigations in grade 7 and when they were

in grade 8 they learnt about complicated scientific investigations. There were 40 students in the classroom. My research took place in one of the eighth grade classrooms.

3. Data Collection

The activities were implemented to the participants in the second semester of the 2012 academic year. Data were collected by the researcher. The procedures of the activity implementation are as follows:

1.1 Implementing the activities

One classroom was selected out of eight classrooms of eighth-grade students by simple random sampling to be a participant group.

The procedures for implementing the activities are as follows:

1) Students were given the pretest consisting of the scientific inquiry skills test, the nature of scientific inquiry test, and the nature of science test.

2) The implementation of activities begins with first activity: seed size and growth of fast plants, temperature and pollen shape, light and development of fast plants pods, and scientific inquiry activity in which students needed to create their own investigation. Students were assigned to work in groups of five. Record sheets from students were evaluated.

3) The three rapid cycling *Brassica rapa* activities were implemented followed by students conducting their own investigation as mentioned above, based on the problem of growing rapid cycling *B. rapa* in warm temperature. Students worked in groups of five. Students' behaviors were observed throughout the activities.

4) After finishing the instruction, students received the scientific inquiry skills test, the nature of scientific inquiry test, and the nature of science. The Questionnaire of Science Attitude Scale for Middle School Students (SASMSS) was offered to students to express their attitude toward science.

During the instruction, the researcher observed and recorded the data about the teaching-learning processes, classroom atmosphere, learning environment, and students' behavior that occurred in class in order to gain more information.

4. Data Analysis

In this study, data were quantitative. Quantitative data were analyzed using the program of Statistical Package for the Social Sciences for Windows (SPSS for Windows). Qualitative data were analyzed and interpreted in terms of a descriptive report.

Basic statistics such as Percentage, Mean, and Standard Deviation were used to analyze the achievement scores, scientific investigation scores, nature of scientific inquiry scores, and mean score from the questionnaire. T-test was also used to determine the significant difference between the means of the posttest scores of students.

The framework of the study and an instructional sequence that shows the summary of this study is identified below:



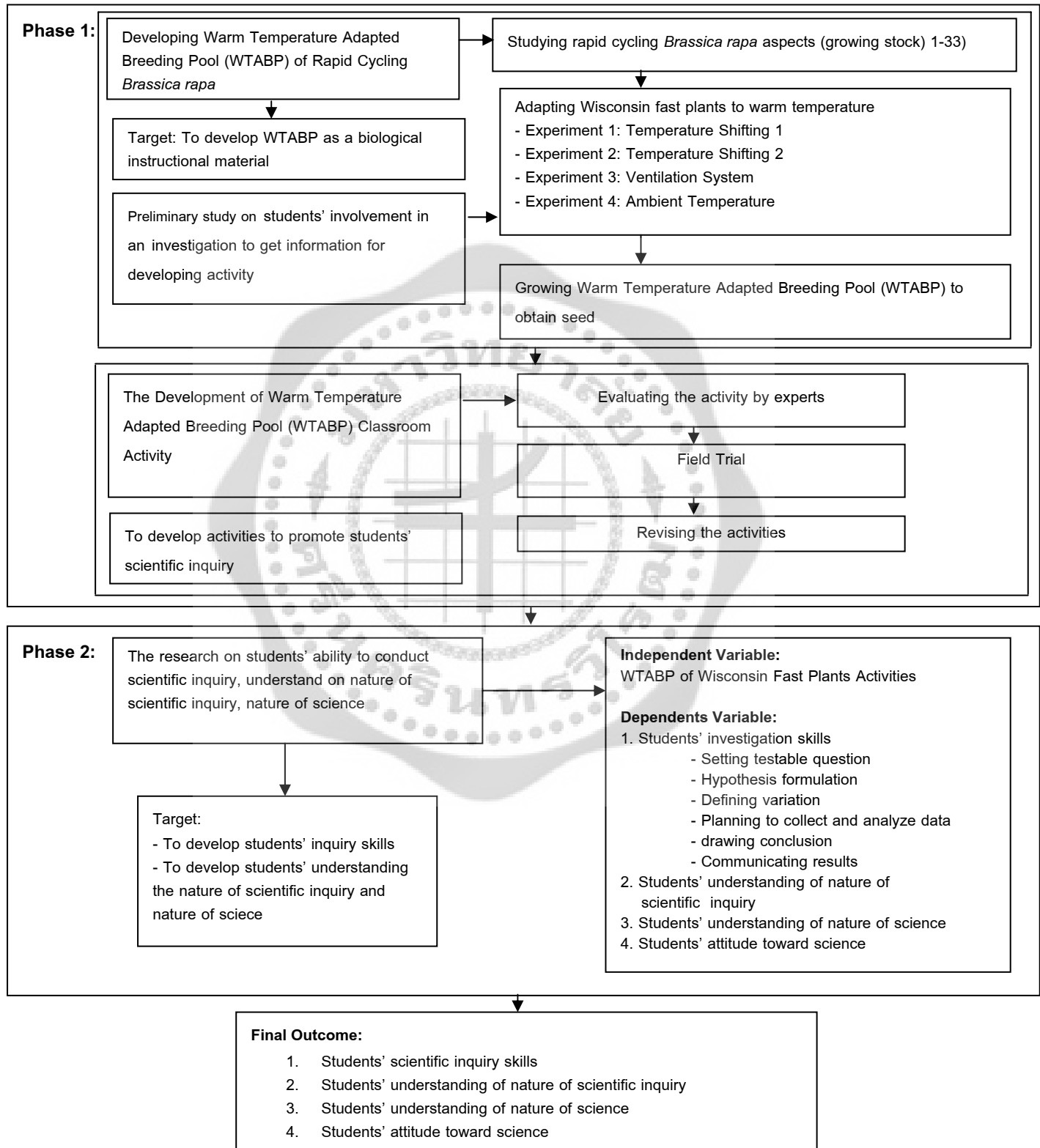


FIGURE 10 THE FRAMEWORK OF THE STUDY

CHAPTER 4

RESULTS OF THE STUDY

This chapter presents the results of the study which focus on developing the Warm Temperature Adapted Breeding Pool of Rapid Cycling *Brassica rapa* and implementing of its activities. The research methodology consisted of two main phases including development of biological instructional materials and research on students' ability to conduct scientific inquiry, understand the nature of scientific inquiry and nature of science. In this chapter, data were gathered and also presented from the first and the second phase which included the result of the students' scientific inquiry skill, nature of scientific inquiry, nature of science, and attitude toward science.

PHASE I THE DEVELOPMENT OF BIOLOGICAL INSTRUCTIONAL MATERIALS

This phase consists of two main sections. The first presents the result of developing warm temperature adapted breeding pool of rapid cycling *Brassica rapa* and the second is the preliminary study on students' involvement in realistic investigation. Rapid cycling *B. rapa* has been used in science classroom in the USA and it grows well in temperature of 22-26 °C. The development of warm temperature adapted breeding pool of rapid cycling *B. rapa* tried to adapt the plants to grow in warm temperature of Thailand. There are four steps of experiments in order to adapt the plants to warm temperature. Two experiments took place at the Science House in University of Wisconsin--Madison. Another two took place in Chaiphum, Thailand.

The second is the preliminary study on students' involvement in realistic investigation. There are three eight grade students involved in the two experiments that took place in Chaiphum. In order to study their investigative skills, understanding of nature of science, and knowledge of flowering plants life, they must involve in every step of the last two experiments from the sowing day until the harvest day. Before the investigation started, students were explained the purpose of the study, information of rapid cycling *B. rapa* and the results of its first two experiments.

The View of Nature of Scientific Inquiry (VNOSI) (Lederman et al., 2002) was also given to them in order to study their understanding of nature of science.

1. The results of developing warm temperature adapted breeding pool of rapid cycling

Brassica rapa

The main purpose of the study was to adapt rapid cycling *Brassica rapa* to warm temperature of Thailand. A standard stock 1-33 was used throughout this study. To produce the warm temperature adapted breeding pool of rapid cycling *Brassica rapa*, four experiments were set up including temperature shifting 1, temperature shifting 2, ventilation system, and ambient temperature. The result of each experiment was as follows:

1.1 The result of temperature shifting 1

This experiment was conducted in a laboratory at the Science House, University of Wisconsin–Madison. The purpose of this experiment was to examine the effects of heat stress during flowering on yield and yield components of *Brassica rapa*. The seeds that demonstrate the shortest time on developing reproductive organ at warm temperature were selected. The plants were grown in two temperatures: 28 and 32 degree Celsius in order to find out if the plants could reproduce. The experiment design is as follows.

Seeds of a standard stock 1-33 were sown in 140 pots with four seeds in each pot. The pots were separated into two groups: group 1 and group 2 with 70 pots in each group. Each group composed of 10 subgroups, which contained seven pots in each subgroup. Both of group 1 and 2 were put into 35°C. Group 1 was moved from 35°C to 32°C. Group 2 was moved from 35°C to 28°C. More detail of the experiment was provided in Chapter 3. Seeds from the plants that could reproduce in small range of time were selected to use for the next experiment.

The results demonstrated that the first generation of rapid cycling *Brassica rapa* could develop and reproduce in warm temperature. The shortest range of time that the plants could produce seeds was 6-8 day in warm temperature both in temperature of 28°C and 32°C. It means that the plants can tolerate heat at that range of time.

The characteristic of the plants after the experiment

- 1) The plants was as small as those of the mother (stock 1-33) and needed small space for growing.
- 2) They germinated on day 2 as the mother generation did.
- 3) Flower bud was found on day 7.
- 4) Flower open on day 13-14
- 5) Life cycle of the plants was 40-45 days.
- 6) Color of seeds was changed. It is lighter than the seed of mother generation.
- 7) Shape of seed also changed. Standard seed shape is round but seeds gained from the experiments were flatter.

Seeds from that range of time were used for the experiment temperature shifting 2. The seeds gained from this experiment were considered "generation 1".

1.2 The result of temperature shifting 2

Seeds from experiment 1 were selected to sow in this experiment. This experiment was also conducted in a laboratory at the Science House, University of Wisconsin–Madison. The purpose of this experiment was to select the seeds that demonstrate the shortest time on developing reproductive organ at warm temperature. Seeds were sown in 30 pots with four seeds in each pot. The pots were separated into two groups: group 1 and group 2 with 15 pots in each group. Each group composed of five subgroups, which contained three pots in each subgroup. Both of group 1 and 2 were put into 35°C. In group one, the first subgroups will be moved from 35°C to 32°C on day 7, and the rest of the subgroup were moved consecutively. The plants were grown at 32°C until open flower are obtained (day 14) and pollination were performed on days 15 to 18. One pot in each subgroup was moved back to 35°C every two days after pollination (range from days 20 to 24). The plants in group two were treated the same as those of group one but the plants were moved from 35°C to 28°C instead. While the reproductive organs were developing, the plants were observed very closely.

The result demonstrated that the second generation of rapid cycling *Brassica rapa* could develop and reproduce in warm temperature. The shortest range of time that the plants could produce seed was 5 days. However, some characteristics of the plant were changed; for instance, the plants took longer to produce flowers and its life cycle was also longer. Seeds from that range of time were used for the next experiment.

The characteristic of the plants after the experiment

- 1) The plants was small as those of the mother (generation 1) and needed small space for growing.
- 2) They germinated on day 2 as the mother generation did.
- 3) Flower bud was found on day 7.
- 4) Flower open on day 13-14
- 5) Life cycle of the plants was 40-45 days.
- 6) Color of seeds changed. It was lighter than the seed of mother generation.
- 7) Shape of seed also changed. Standard seed shape is round but seeds gained from the experiments were flatter.

Seeds from this experiment were considered "generation 2".

1.3 The result of ventilation system

This experiment took place in Chaiyaphum, Thailand. To prepare the use of rapid cycling *Brassica rapa* in Thai science classroom, there were three eight grade students involved in the experiment. They helped to observe, measure, make pollination during all steps of the experiment. More detail was provided in the next section.

Seeds from experiment 2 were selected to sow in this experiment. The experiment was performed in ambient temperature, about 35°C at day time and 28°C at night time. Ventilation system (fan) was used during reproductive organ development in order to control the temperature about 33°C.

The result showed that the plants could grow and reproduce. But some characteristics of the plants were changed as follows.

The characteristic of the plants after the experiment

- 1) The plants was small as those of the mother (generation 2) and needed small space for growing.
- 2) They germinated on day 2 as the mother generation did.
- 3) Flower bud was developed on day 8-9.
- 4) Flower open on day 15-16
- 5) Life cycle of the plants was 45-50 days.
- 6) Color of seeds changed. It was lighter than the seed of mother generation.
- 7) Shape of seed also changed. Standard seed shape is round but seeds gained from the experiments were flatter.

Seeds from this experiment were considered "generation 3".

As mentioned in chapter 2 that rapid cycling *Brassica rapa* completed their life cycle within 40-45 days. In this experiment, the life cycle took longer than the same. The plants took 45-50 days to complete their life cycle.

1.4 The result of ambient temperature

Seeds from experiment 3 were selected to sow in experiment 4. This experiment was conducted in ambient temperature. As in the experiment 3, students were involved in this experiment. The plant was carefully observed during reproduction time (days 7 to 18).

The result of this experiment demonstrated the ability of the plants to grow in warm temperature of Thailand in the range of temperature 22-35°C. As mentioned in the experiment of temperature shifting 1, of temperature shifting 2 and of ventilation system, some characteristics of the plants were changed. Below are lists of changing of rapid cycling *Brassica rapa* after the fourth experiment.

The characteristics of the plants after the experiment

- 1) The size of the plants is smaller than that of the mother generation.
- 2) Color of seed was lighter.
- 3) Flower bud was developed on days 8-9.
- 4) Shape of the seed is not round as the mother generation was but flat instead.

Even seed shape was changed but germination time was still one day as that of the mother.

- 5) The flower opens on days 15-16 instead of days 13-14.
- 6) The plants could tolerate to warm temperature. The range of optimum is 22-32°C.
- 7) Life cycle of the plants took longer than usual. It took 45-50 days to complete one cycle of their life.
- 8) Seed pods were shorter.
- 9) Germination percentage was 93.75.

In conclusion, the plants could grow and reproduce in warm temperature of Thailand. Seeds were obtained through the four experiments. The ability to germinate is still the same which is on day 2. However, even the plants could adapt themselves to warm temperature as we could see from the last experiment. Thailand's climate is still too warm and too humid to grow the plants; therefore, more breeding experiments are needed in the future.

Summary of the results of developing warm temperature adapted breeding pool of rapid cycling *Brassica rapa* are below.

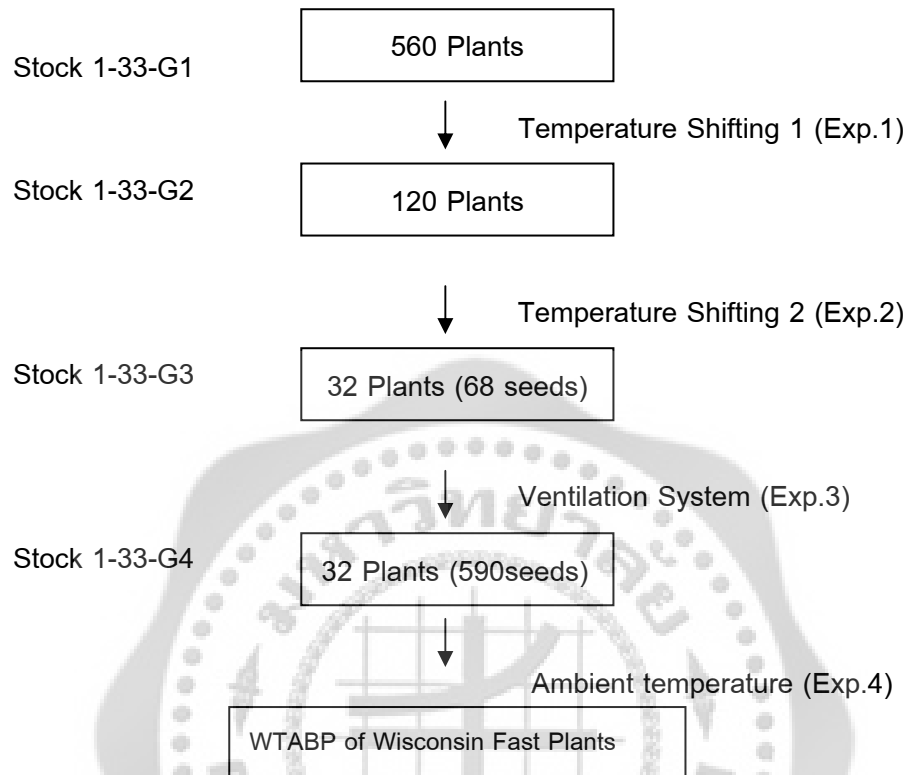


FIGURE 11 SCHEMATIC FOR DEVELOPING WTABP OF RAPID CYCLING *Brassica rapa*

2. The result of preliminary study on students' involvement in realistic investigation

As mentioned in Chapter 3 and the previous section that there were three eight grade students involved in developing warm temperature adapted breeding pool of rapid cycling *Brassica rapa*. Their ability to conduct scientific inquiry and understand nature of science was studied using View of Nature of Scientific Inquiry (VNOSI) and semi-structured interview form. The results of students' involvement in realistic investigation are below.

2.1 Students' investigative skills

The analysis of students' investigation skill was based on observations of their behavior throughout the research, their laboratory notebooks, their performance on the VOSI-S before and after the research, and the interview forms. The results indicate that

students' investigative skills improved throughout the course of study. The research on adapting rapid cycling *Brassica rapa* to warm temperature helped to improve students' ability to ask questions, make predictions, and collect data. Examples of questions from observations and laboratory notebooks are shown below:

- Why do we use soil from the store instead of soil from the land?
- What will happen if we turn off the light at nighttime?
- What will happen if we use a different type of fertilizer?
- Does light affect plant germination?

Students' expression could be investigated for most questions. Unfortunately, they rarely generated the correct hypotheses from the questions they proposed. The students' ability to make predictions also improved due to the fact that they made observation and collected data each day (in addition to repeating the experiment). Through their involvement in the research, they became familiar with rapid cycling *Brassica rapa* lifecycle and environment. Using the data they collected, the students were able to predict what would happen if some feature of the environment change. For example:

- Not enough light makes plants elongate more than usual.
- If the temperature is too high, we will get some abnormal flowers/pollens.
- If we put too much fertilizer on the plants, they will die.

Based on their observation of rapid-cycling *Brassica rapa*, students' appeared to improve in their ability to observe, predict, and use tools to measure and record numeric and descriptive characteristics of the plants. Students also became confident in observing and collecting data and sharing them with each other.

The following were taken from interviews with the students:

Student 1: "Being involved in this research helped to improve my ability to ask testable questions. I enjoyed observing the development of the plants and using tools to measure and collect the data. The plants grew very fast and changed stages every day. That made me wonder about them. I got a better understanding of the scientific inquiry process than ever before."

Student 2: "I observed the growth and development of Fast Plants every day. I enjoyed measuring and collecting the data while being involved in the experiment. It's a great opportunity to practice my investigative skills."

Students 3: "I have never done a real scientific investigation. This is the first time I've done an experiment like scientists do. I have learned a lot about how to observe and investigate things. This plant is amazing. It made me curious, and I had questions every day I came to the lab."

Despite these positive experiences, students struggled during some stages of the scientific inquiry process, such as making hypotheses, designing investigations, and analyzing and interpreting the data. The researcher's observations and the students' laboratory notebooks revealed that they wrote many questions but developed the wrong explanations. Therefore, the students designed experiments that did not support the questions or the hypotheses. They were often "stuck" and needed more assistance at these stages.

2.2 Students' understanding of the nature of science

Based on the current findings, students' views of the nature of science changed in terms of the necessity of evidence in science. They came to realize that science requires evidence to support hypotheses. However, the students did not improve in other areas relating to the nature of science, such as: (1) methods of scientific investigation (including the role of hypotheses and the design of experiments); (2) the significance of theories in scientific inquiry (including thoughts on observations and inferences); (3) the tentative nature of science (including warrant for belief and the status of laws and theories); (4) creativity in science (before, during, and after data collection); (5) social, political, economic, and cultural influences on science; (6) research funding issues, academic freedom, and ethics; (7) collaboration and competition; and (8) the peer review process.

2.3 Students' knowledge of flowering plant

Students were asked to write their prior knowledge of the lifecycles of flowering plants before and after conducting the research. They were also interviewed about biology of plants before the research. The results showed that their knowledge of flowering plants increased after performing the experiments. The following quotes were taken from the interviews:

Student 1: "The lifecycle of Rapid cycling Brassica rapa is very fast. I observed every stage of growth. I know more about germination, pollination and how the environment affects the plants' growth."

Student 2: "I observed and recorded Rapid cycling Brassica rapa's lifecycle every day. I found that my knowledge of plants increased. I know that nutrients, water, and space are necessary for plant growth and development. From the experiment, I found that temperature affected rapid cycling Brassica rapa growth."

Student 3: "rapid cycling Brassica rapa hardly grow in warm temperatures, and they need light 24 hours a day. They are very sensitive to environmental changes. I compared Rapid cycling Brassica rapa to other kinds of plants and found that each kind of plants needs a different environment."

Based on the students' writings about the research, it appears as though they became more familiar with technical terms about plants. Their writing focused on the effects of the environment on *Brassica rapa* lifecycle. Students mentioned that temperature and light were the most important factors in the growth and development of plants indicating that plants need proper the temperature and light for growth and photosynthesis. Their writings demonstrated that the students could identify the characteristics of the reproductive organs, and also indicated that different plants showed variations in pollen, stigma, the number of pollen grains, and the number and color of petals.

PHASE II THE RESEARCH ON STUDENTS' ABILITY TO CONDUCT SCIENTIFIC INQUIRY, UNDERSTAND THE NATURE OF SCIENTIFIC INQUIRY AND NATURE OF SCIENCE

The purpose of this phase was to use the activities of adapted rapid cycling *Brassica rapa* to enhance students' ability to conduct scientific inquiry, students' understanding of nature of scientific inquiry and of nature of science. The activities were implemented in a classroom of 40 eight grade students at Chaturatwittayakarn School during the second semester in the 2011 academic year. The results of students' learning outcome include the students' ability to conduct scientific inquiry, students' understanding of nature of scientific inquiry, student's understanding of nature of science, and students' attitude toward science. Data were collected to test research hypothesis.

Data collection included pre-test and post-test of students' ability to conduct scientific inquiry score, students' understanding of nature of scientific inquiry score, and students' understanding of nature of science score. The students' attitude toward science was investigated after the implementation.

To test the research hypothesis, students' ability to conduct scientific inquiry score, students' understanding of nature of scientific inquiry score, and students' understanding of nature of science score were compared with the cutting score at the 0.05 level of significance. Students' attitude toward science was at high level at the 0.05 level of significance. The results of testing these hypotheses are presented in the following section.

1. The result of students' scientific inquiry skill

The results of student's scientific inquiry skills are presented in three parts, 1) The comparison of pre-test and post-test score, 2) The setting of cut-off score that provides the results of setting the cutting score of each test. 3) Testing the hypothesis that provides the results of the inferentially statistic comparing the students' ability to conduct scientific inquiry score and the criterion score as the testing of the research hypothesis.

1.1 The comparison of pre-test and post-test score

Using the scientific inquiry skills test, the data of students' scientific inquiry skills score were gathered at the beginning and the end of the activity implementation. This part presented the comparison of students' scientific inquiry skills score in each aspect, comparison of students' students' scientific inquiry skills score in total, and the result of scientific investigation which presented in mean score and standard deviation.

1) The results of students' scientific inquiry skills score in each aspect

Table 5 showed the comparison of the students' scientific inquiry skills score in each aspects before and after using the rapid cycling *Brassica rapa* activity.

TABLE 5 THE COMPARISON OF THE STUDENTS' SCIENTIFIC INQUIRY SKILLS
SCORE IN EACH ASPECT BEFORE AND AFTER USING THE ACTIVITY
ACCORDING TO THE MAIN STUDY

Characteristic of Scientific Inquiry skills	Pre-test score		Post-test score		Total score	t	p
	Mean	S.D.	Mean	S.D.			
Setting testable question	2.35	0.76	5.92	2.22	8	10.60*	.00
Hypothesis formulation	4.15	0.74	7.98	2.88	12	7.88*	.00
Defining variation	18.12	5.18	24.70	3.14	28	6.75*	.00
Planning to collect and analyze data	7.63	2.52	11.00	3.06	16	5.44*	.00
Drawing conclusion	6.10	2.07	8.05	0.33	12	5.10*	.00

$p < 0.05$

The result showed that mean score of post-test in every aspect of scientific inquiry skills were higher than that of the pre-test at the 0.05 level of significance. It means the students who have done the activity of rapid cycling *Brassica rapa* had significantly improved their scientific inquiry skills.

2) The results of students' scientific inquiry skills score in total

Table 6 showed the comparison of the students' scientific inquiry skills total score before and after using the rapid cycling *Brassica rapa* activity.

TABLE 6 THE COMPARISON OF THE STUDENTS' SCIENTIFIC INQUIRY SKILLS TOTAL
SCORE BEFORE AND AFTER USING THE ACTIVITY ACCORDING TO THE MAIN
STUDY

Score	N	Mean	S.D	t	p
Students scientific inquiry skills pre-test score	40	38.35	7.04	11.53*	.00
Students scientific inquiry skills post-test score	40	57.65	8.57		

$p < 0.05$

The results from Table 6 indicated that the students' scientific inquiry skills mean score after the activity implementation was higher than before at the 0.05 level of significance. It means the students who have done the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* had significantly improved their scientific inquiry skills.

3) The results of students' scientific communication

Table 7 showed the results of students' scientific communication, one of scientific inquiry skills, after using the rapid cycling *Brassica rapa* activity.

TABLE 7 THE RESULTS OF STUDENTS' SCIENTIFIC COMMUNICATION MEAN SCORE AFTER USING RAPID CYCLING *Brassica rapa* ACTIVITY ACCORDING TO THE MAIN STUDY

Scientific communication	Result (N=40)		
	Mean	S.D.	Interpretation
Problem	3.72	0.45	Highest
Procedure	3.00	0.00	High
Data and result	3.55	1.08	Highest
Conclusion	3.00	0.00	High
Content knowledge	3.60	0.50	Highest
Coherence and organization	3.50	0.51	High
Creativity	3.88	0.33	Highest
Supporting Information	3.28	0.85	High
Speaking skill	3.88	0.33	Highest
Delivery	3.75	0.44	Highest
Total	3.57	0.63	Highest

The results showed that students' scientific communication mean score after finishing the Rapid cycling *Brassica rapa* activity was favorable to students at 3.57 which is the highest level.

TABLE 8 THE COMPARISON OF STUDENTS' SCIENTIFIC COMMUNICATION MEAN SCORE WITH CRITERION AFTER USING RAPID CYCLING *Brassica rapa* ACTIVITY ACCORDING TO THE MAIN STUDY

The Test	Mean	Criterion Score	S.D.	t	p
Problem	3.72	2.51	0.45	16.99*	.00
Procedure	3.00	2.51	0.00	-	-
Data and result	3.55	2.51	1.08	6.06*	.00
Conclusion	3.00	2.51	0.00	-	-
Content knowledge	3.60	2.51	0.50	13.90*	.00
Coherence and organization	3.50	2.51	0.51	12.37*	.00
Creativity	3.88	2.51	0.33	25.78*	.00
Supporting Information	3.28	2.51	0.85	5.71*	.00
Speaking skill	3.88	2.51	0.33	25.78*	.00
Delivery	3.75	2.51	0.44	17.88*	.00

p < 0.05

The result showed that mean score in every aspect of scientific communication were higher than the criterion score at the 0.05 level of significance. It means the students who have done the activity of rapid cycling *Brassica rapa* had significantly improved their scientific communication.

1.2 The setting of cut-off score for scientific inquiry skills

The cut-off score was used as a criterion-referenced score for comparing with the mean score of scientific inquiry skills post-test. The students who had studied through the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* in the field trial study were defined as the instructed group while the students who had not studied with the activity yet in the main study were defined as the uninstructed group. After constructing the distribution graphs, the instructed and uninstructed group score

distributions are the primary determinants of the tests whether or not they can be classified students as true masters and true non-masters of an objective. The post-test score of trial study group and the pre-test score of main study group were used by plotting a graph of frequency of student numbers in each score. The result of graph plotting showed cutting point as shown in Figure 12.

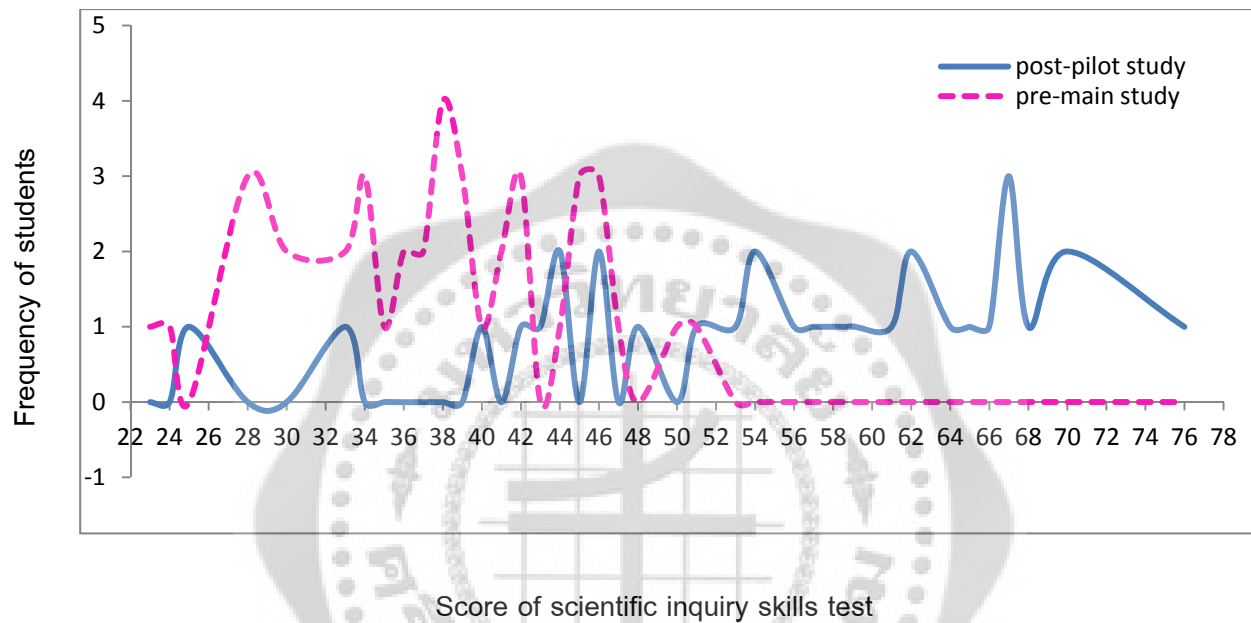


FIGURE 12 THE GRAPH OF THE FREQUENCY NUMBER OF STUDENT IN EACH SCORE OF THE SCIENTIFIC INQUIRY SKILLS TEST

The range of scores around the point at which the distributions intersected was calculated to obtain the optimal cutting score. The result of the calculation is presented in Table 9.

TABLE 9 THE RESULT OF CALCULATING THE CUTTING SCORE FOR SCIENTIFIC INQUIRY SKILLS TEST

score	probability of correct decisions	probability of incorrect decisions	validity coefficient
45	0.77	0.23	0.54
46	0.81	0.19	0.62
47	0.83	0.17	0.65
48*	0.84	0.16	0.69
49	0.83	0.17	0.66

$p < 0.05$

The cut-off score for the scientific inquiry skills test is 48. This score obtained the highest probability of correct decisions and the lowest probability of incorrect decisions. The score would be used as the criterion-referenced score for testing the first hypothesis.

1.3 Testing the first hypothesis

The first hypothesis stated that students' scientific inquiry skill mean score after the instruction was higher than the cutting score of scientific inquiry test. To test this hypothesis, a one sample t-test statistic was used to compare the student's mean score and the cutting score to see whether there was a significant difference between them. This method examined whether the student's mean score was significantly higher than the cutting scores. Table 10 showed the result of this statistical calculation.

TABLE 10 THE COMPARISON OF THE SCIENTIFIC INQUIRY SKILL MEAN SCORE WITH THE CUT-OFF SCORE FOR THE SCIENTIFIC INQUIRY SKILL TEST

The test	N	Cut-off score	Mean	S.D	t	p
After using the activity	40	48	57.65	8.57	7.13*	.00

$p < 0.05$

The result showed that the mean score were significantly higher than the cut-off score (criterion scores) at the 0.05 level of significance. The result supported the first hypothesis.

In conclusion, the result of students' scientific inquiry skills indicated that after doing the activity, the students had significantly improved their scientific inquiry skills, and the scientific inquiry skill mean score was significantly higher than the criterion score.

2. The result of student's understanding of nature of scientific inquiry

The results of student's understanding of nature of scientific inquiry are presented in three parts. 1) The comparison of pre-test and post-test score, 2) The setting of cut-off score that provides the results of setting the cut-off score of the tests. It would be used as a criterion-referenced score comparing to the post-test score of the main study. 3) Testing the second hypothesis that provides the results of the inferential statistic comparing the students' understanding of nature of scientific inquiry score and the criterion score as the testing of the research hypothesis.

2.1 The comparison of pre-test and post-test score

Using the nature of scientific inquiry test, the data of students' understanding of nature of scientific inquiry score were gathered at the beginning and the end of the activity implementation. This part showed the students' score in each aspect of nature of scientific inquiry and their total scores.

1) The comparison of pre-test and post-test score in each aspect

Table 11 showed the comparison of the students' understanding of nature scientific inquiry score in each aspects before and after using the rapid cycling *Brassica rapa* activity.

TABLE 11 THE COMPARISON OF THE STUDENTS' UNDERSTANDING OF NATURE OF SCIENTIFIC INQUIRY SCORE IN EACH ASPECT BEFORE AND AFTER USING THE ACTIVITY ACCORDING TO THE MAIN STUDY

Aspects of nature of scientific Inquiry	Pre-test score		Post-test score		Total score	t	p
	Mean	S.D.	Mean	S.D.			
Multiple methods of scientific investigation	2.00	0.60	2.48	0.68	4	3.04*	.00
Multiple purposes of scientific investigation	2.05	0.32	2.45	0.60	4	3.77*	.00
Justification of scientific knowledge	6.05	1.15	7.65	2.23	12	3.97*	.00
Recognition and handling of anomalous data	3.75	0.93	5.15	1.21	8	5.597*	.00
Distinctions between data and evidence	1.90	0.50	2.8	1.04	4	5.65*	.00
Community of practice	11.00	1.80	12.95	2.16	16	4.11*	.00

p<0.05

The result showed that mean score of post-test in every aspect of nature of scientific inquiry were higher than the pre-test at the 0.05 level of significance. It means the students who have done the activity of rapid cycling *Brassica rapa* had significantly improved their understanding on nature of scientific inquiry.

2) The results of students' understanding of nature of scientific inquiry score in total

Table 12 showed the comparison of the students' understanding of nature of scientific inquiry score in total before and after using the rapid cycling *Brassica rapa* activity.

TABLE 12 THE COMPARISON OF THE STUDENTS' UNDERSTANDING OF NATURE OF SCIENTIFIC INQUIRY TOTAL SCORE BEFORE AND AFTER USING THE ACTIVITY ACCORDING TO THE MAIN STUDY

Score	N	Mean	S.D	t	p
Student's understanding of nature of scientific inquiry pre-test score	40	26.73	2.54	8.11*	.00
Student's understanding of nature of scientific inquiry post-test score	40	33.48	4.11		

p<0.05

The results from Table 10 indicated that the students' understanding of nature of scientific inquiry mean score after the activity implementation was higher than before at the 0.05 level of significance. It means the students who have done the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* had significantly improved their understanding of nature of scientific inquiry.

2.2 The setting of cut-off score for nature of scientific inquiry

The cut-off score was used as a criterion-referenced score for comparing with the mean score of student's understanding of nature of scientific inquiry post-test. The students who had studied through the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* in the field trial study were defined as the instructed group while the students who had not studied with the activity yet in the main study were defined as the uninstructed group. After constructing the distribution graphs, the instructed and uninstructed group score distributions are the primary determinants of the tests whether or not they can be classified students as true masters and true non-masters of an objective. The post-test score of trial study group and the pre-test score of the main study group were used by plotting a graph of frequency of student numbers in each score. The result of graph plotting showed cutting point as shown in Figure 13.

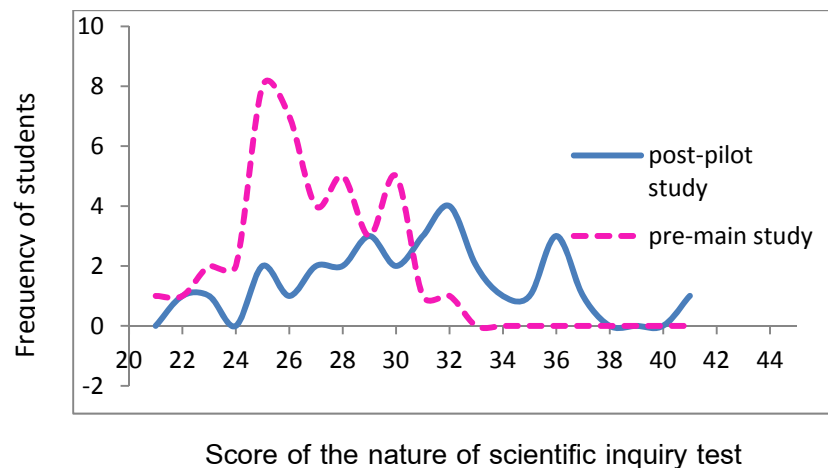


FIGURE 13 THE GRAPH OF THE FREQUENCY NUMBER OF STUDENTS IN EACH SCORE OF THE NATURE OF SCIENTIFIC INQUIRY TEST

In the next step, the range of scores around the point at which the distributions intersected was calculated to obtain the optimal cutting score. The result of the calculation is presented in Table 13.

TABLE 13 THE RESULT OF CALCULATING THE CUT-OFF SCORE FOR NATURE OF SCIENTIFIC INQUIRY TEST

score	probability of correct decisions	probability of incorrect decisions	validity coefficient
29	0.73	0.27	0.45
30	0.73	0.27	0.44
31*	0.77	0.23	0.55
32	0.74	0.26	0.51
33	0.70	0.30	0.45

The cut-off score for the nature of scientific inquiry test is 31. This score obtained the highest probability of correct decisions and lowest probability of incorrect decisions. The score would be used as the criterion-referenced score for testing the second hypothesis.

2.3 Testing the second hypothesis

The second hypothesis stated that students' understanding of nature of scientific inquiry mean score was higher than the cutting score of nature of scientific inquiry test. To test this hypothesis, a one sample t-test statistic was used to compare the student's mean score and the cutting score to see whether there was a significant difference between them. This method examined whether the student's mean score was significantly higher than the cutting scores. Table 14 showed the result of this statistical calculation.

TABLE 14 THE COMPARISON OF THE NATURE OF SCIENTIFIC INQUIRY MEAN SCORE WITH THE CUT-OFF SCORE FOR THE NATURE OF SCIENTIFIC INQUIRY TEST

The test	N	Cut-off score	Mean	S.D	t	p
After using the activity	40	31	33.48	4.11	3.81*	.00

$p < 0.05$

The result showed that the mean score were significantly higher than the cut-off score (criterion scores) at the 0.05 level of significance. The result supported the second hypothesis.

In conclusion, the result of students' understanding of nature scientific inquiry skills indicated that after doing activity, the students had significantly improved their understanding on nature of scientific inquiry, and the nature of scientific inquiry mean score was significantly higher than the criterion score.

3. The result of students' understanding of nature of science

The results of student's understanding of nature of science is presented in threeparts: 1) The comparison of pre-test and post-test score, 2) The setting of cut-off score. It would be use as a criterion-referenced score comparing to the post-test score of main study, and 3) Testing the third hypothesis that provides the results of the inferentially

statistic comparing the student's understand of nature of science score and the criterion score as the testing of the research hypothesis.

3.1 The comparison of pre-test and post-test score

Using the nature of science test, the data of students' understanding of nature of science score were gathered at the beginning and the end of the activity implementation. Table 15 showed the comparison of the students' understand of nature of science score before and after using the activity.

TABLE 15 THE COMPARISON OF THE STUDENTS' UNDERSTANDING OF NATURE OF SCIENCE SCORE BEFORE AND AFTER USING THE ACTIVITY ACCORDING TO THE MAIN STUDY

Score	N	Mean	S.D	t	p
Student's understanding of nature of science pre-test score	40	24.83	3.77	5.20*	.00
Student's understanding of nature of science post-test score	40	28.53	4.43		

$p < 0.05$

The results from Table 15 indicated that the students' understanding of nature of science mean score after the activity implementation was higher than before at the 0.05 level of significance. It means the students who have done the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* had significantly improved their understanding of nature of science.

3.2 The setting of cut-off score for nature of science

The cut-off score was used as a criterion-referenced score for comparing with the mean score of student's understanding of nature of science post-test. The post-test score of trial study group and the pre-test score of main study group were used by plotting a graph of frequency of student numbers in each score. The result of graph plotting showed cutting point as shown in Figure 14.

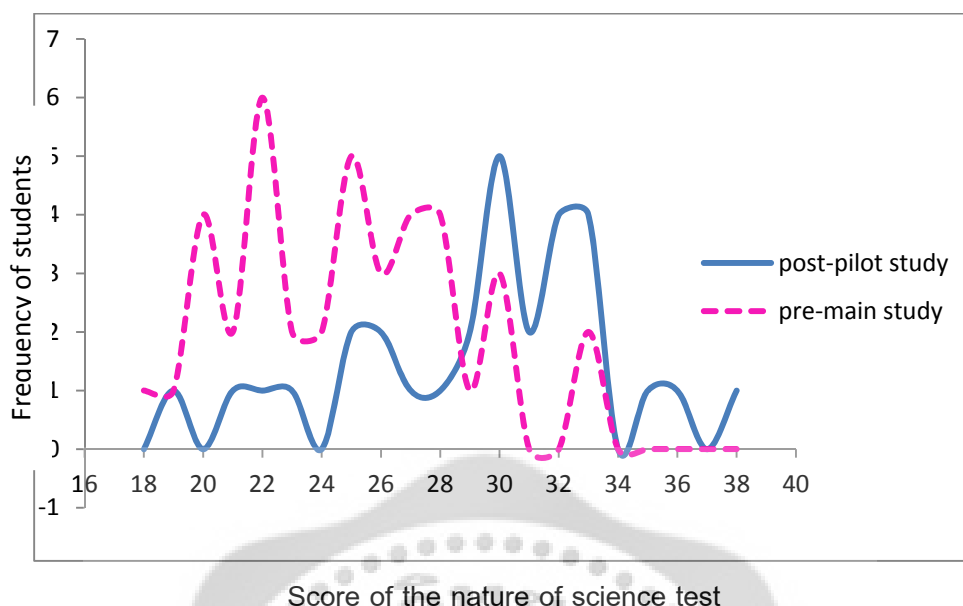


FIGURE 14 THE GRAPH OF THE FREQUENCY NUMBER OF STUDENT IN EACH SCORE OF THE NATURE OF SCIENCE TEST

The range of scores around the point at which the distributions intersected was calculated to obtain the optimal cutting score. The result of the calculation is presented in Table 16.

TABLE 16 THE RESULT OF CALCULATING THE CUT-OFF SCORE FOR NATURE OF SCIENCE TEST

score	probability of correct decisions	probability of incorrect decisions	validity coefficient
27	0.69	0.31	0.38
28	0.73	0.27	0.45
29*	0.77	0.23	0.53
30	0.76	0.24	0.50
31	0.73	0.27	0.46

The cut-off score for the nature of science test is 29. This score obtained the highest probability of correct decisions and the lowest probability of incorrect decisions. The score would be used as the criterion-referenced score for testing the second hypothesis.

3.3 Testing the third hypothesis

The second hypothesis stated that students' understanding of nature of science mean score was higher than the cut-off score of nature of science test. To test this hypothesis, a one sample t-test statistic was used to compare the students' understanding of nature of science mean score and the cutting score to see whether there was a significant difference between them. This method examined whether the students' understanding of nature of science mean score was significantly higher than the cutting scores. Table 17 showed the result of this statistical calculation.

TABLE 17 THE COMPARISON OF THE NATURE OF SCIENCE MEAN SCORE
WITH THE CUT-OFF SCORE FOR THE NATURE OF SCIENCE TEST

The test	N	Cut-off score	Mean	S.D	t	p
After using the activity	40	29	28.53	4.43	.679	.50

$p < 0.05$

The result showed that the mean score was lower than cut-off score. It was not significantly different at 0.05 level of significance. The result did not supported the hypothesis.

4. The result of students' attitude toward science

To assess the students' attitude toward science, the questionnaire of science attitude scale for middle school students was used to gather the data at the end of activity. The instrument was developed based on five point Likert scale questionnaire ranging from strongly agree, agree, undecided, disagree, and strongly disagree. The gathered data of

student's attitude toward science and the research hypothesis testing were presented as follows:

The gathered data on student's attitude toward science

After the activity, students were asked to express their attitude toward science. The mean score, standard deviation, and the result of student's attitude toward science are presented in Table 18.

TABLE 18 STUDENTS' ATTITUDE TOWARD SCIENCE

List of evaluation	Result (N=40)		
	Mean	S.D.	Interpretation
1. Getting science books from the library make me bore	4.50	0.64	High level
2. I hate to keep records of science experiments in a notebook	4.65	0.48	High level
3. Science films is boring for me	4.58	0.55	High level
4. I wish science class lasted all day	3.55	1.04	High level
5. I dislike watching science special on television	3.92	0.92	High level
6. I hate science class	4.05	0.60	High level
7. Learning science facts is boring	3.98	0.95	High level
8. Working with science equipment makes me feel important	4.20	0.76	High level
9. I would like to join a science club that meets after school	3.98	0.86	High level
10. Looking through a microscope is not my idea of fun	4.10	0.87	High level
11. Knowing science facts makes me feel good	4.05	1.06	High level
12. I do not mind doing an experiment several times to check the answer	3.88	1.18	High level

TABLE 18 (continued)

List of evaluation	Result (N=40)		
	Mean	S.D	Interpretation
13. Sharing science facts that I know makes me feel great	4.48	0.64	High level
14. I hate to study science outdoors	4.22	0.83	High level
15. It is neat to talk to my parents about science	3.95	0.78	High level
16. I like to make drawings on science	3.80	0.88	High level
17. I would not think of discussing science with friends	3.68	0.69	High level
18. I enjoy using mathematics in science experiments	3.92	1.00	High level
19. I cannot wait until science class	3.95	0.81	High level
20. I wish we did not have science class so often	4.45	0.60	High level
21. Doing science projects at home is boring	4.12	0.91	High level
22. Science is one of my favorite classes	4.40	0.81	High level
Total mean	4.11	0.88	High level

The data in Table 18 indicated that all aspects were favorable to students at a high level. Moreover, the overall of students' attitude toward science was at a high level.

The forth hypothesis stated that students' attitude towards science was at a high level. The mean score of students' attitude toward science was evaluated comparing with the criteria score. As mentioned in chapter 3, the score 3.51-4.50 is interpreted as a high level of attitude toward science. The total mean is 4.11 which means the result supported the hypothesis.

5. Summary of the research results

This study intended to study students' scientific inquiry skills, students' understanding of nature of scientific inquiry, students' understanding of nature of science, and students' attitude towards science using rapid cycling *Brassica rapa* activity. Student learning outcomes were collected using research instruments for the purpose of testing the research hypotheses. Findings are summarized as follows:

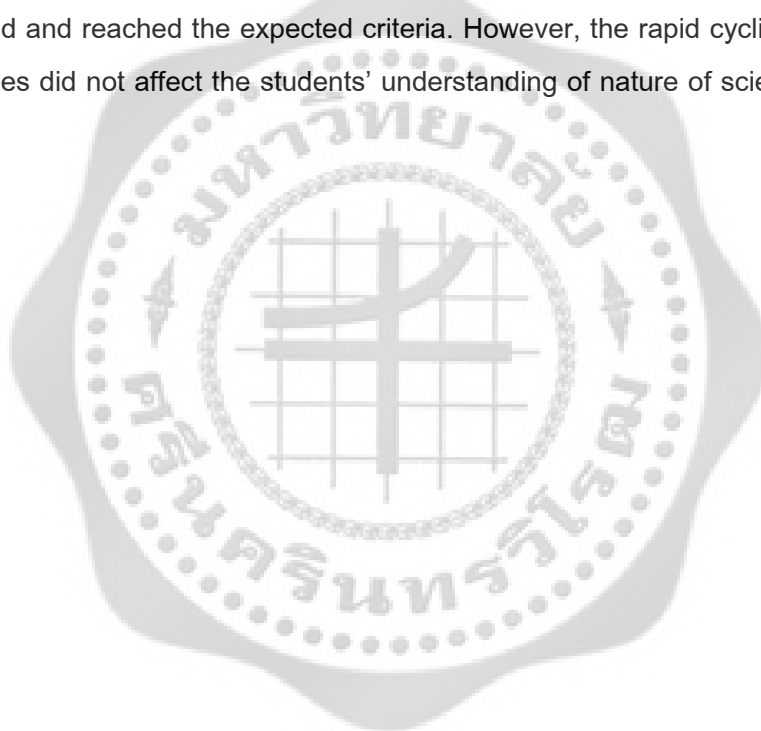
1. After the instruction, the students' scientific inquiry skills mean score was significantly higher than the cut-off score at the 0.05 level of significance.

2. After the instruction, the students' understanding of nature of scientific inquiry mean score was significantly higher than the cut-off score at the 0.05 level of significance.

3. After the instruction, the students' understanding of nature of science mean score was not significantly different at 0.05 level of significance.

4. After the instruction, the students' attitude toward science mean score was at a high level.

In conclusion, the research findings showed that the students' scientific inquiry skills, students' understanding of nature of scientific inquiry, and students' attitude toward science were improved and reached the expected criteria. However, the rapid cycling *Brassica rapa* inquiry activities did not affect the students' understanding of nature of science.



CHAPTER 5

CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

Rapid cycling *Brassica rapa* is an education model for teaching in many aspects of biology and always used to teach scientific inquiry in science classrooms. Special characteristics of the plant make the plants very attractive for teaching students to do science. Unfortunately, it can grow and reproduce at temperature of 22-26°C; therefore, this study intended to develop warm temperature adapted breeding pool of rapid cycling *B. rapa* for Thai science classroom. It means that the plants must be adapted to warm temperature of Thailand before using in classroom. Also, students who participated in the activity using rapid cycling *B. rapa* were expected to improve their scientific inquiry skills, understanding of nature of scientific inquiry, and understanding of nature of science. The students' attitude toward science was also measured by the questionnaire of science attitude scale for middle school students.

1. Objectives of the Study

The objectives of this research study were:

1. To develop Warm Temperature Adapted Breeding Pool of Wisconsin Fast Plants (Rapid Cycling *Brassica rapa*) as a biological instructional material to promote students' investigation skills.
2. To study students' ability to conduct scientific inquiry, understand the nature of scientific inquiry and nature of science using Warm Temperature Adapted Breeding Pool as a tool.

2. Research Hypotheses

1. Students' scientific inquiry skill mean score was higher than the cutting score of scientific inquiry test.
2. Students' understanding of nature of scientific inquiry mean score was higher than the cutting score of nature of scientific inquiry test.
3. Students' understanding of nature of science mean score was higher than the cutting score of nature of science test.
4. Students' attitude towards science was at a high level.

3. Participants

The participants in this research were 40 of eighth grade students in Chatturatwittayakarn School located at Chatturat district, Chaiyaphum province.

4. Research Materials

Materials of this research were classified into two main parts described as follows:

4.1 Rapid cycling *Brassica rapa* activities

Four activities were developed based on the characteristics of rapid cycling *Brassica rapa*. The four activities are seed size and growth of fast plants, temperature and pollen shape, light and development of fast plants pods and the scientific inquiry activity. Students were to conduct their own experiments for the last activity.

4.2 Research instruments for data collection

4.2.1 The scientific inquiry skills test

4.2.2 The nature of scientific inquiry test

4.2.3 The nature of science test

4.2.4 The science attitude scale for middle school students

5. Research Methodology

The research methodology in this study consisted of two main phases including the development of biological instruction and the research on students' ability to conduct scientific inquiry, understand of nature of scientific inquiry, and nature of science using rapid cycling *Brassica rapa* activities. The process of developing and implementing the activities were proceeded as follows:

5.1 Development of Biological Instruction

5.1.1 Development of warm temperature breeding pool of rapid cycling

Brassica rapa

This phase intended to adapt rapid cycling *Brassica rapa* to warm temperature of Thailand. The characteristic and information about the plant were studied. The four experiments: Temperature shifting 1, Temperature shifting 2, Ventilation system, and Ambient temperature were designed to breed the plants. The plants that could grow and reproduce in each experiment were selected to sow for the next generation. The plants that adapted themselves to warm temperature were used to create the scientific inquiry.

Moreover, three students were involved in the last two experiments in order to get preliminary information for developing activity used in classroom. Their investigative skills, understanding of nature of science, and the life cycle of the plants were studied.

5.1.2 Development of Warm Temperature Adapted Breeding Pool (WTABP) Classroom Activity

This part aims students to learn how to do investigation. Students were engaged in an inquiry process by using WTABP. The investigation activities were developed based on usefulness of WTABP of rapid cycling *Brassica rapa*. There are four investigations activities as follows:

1. Seed size and growth of fast plants
2. Temperature and pollen shape
3. Light and development of fast plants pods
4. Scientific inquiry activity

For each of the activities, the validity structure, appropriateness, and the suitability of time allocation of the activity were evaluated by experts: educators, science teachers, and scientists. The experts' suggestions were used for improving the activity. Then, the activities were tried out in a non target science classroom. Each activity needed to be revised before implementing with the participants.

5.1.3 Developing materials for data collection

1) The Scientific inquiry skills test

The scientific inquiry skills test was developed to assess whether the students scientific inquiry skills improved. The test was open-ended. Students were to write down their idea to each question. The test consisted of six items. The draft test was presented to the dissertation advisors and experts for the content validity check, accuracy of the test, appropriateness, precision, and wording. It was revised before using with the participants.

2) Nature of scientific inquiry test

The Nature of scientific inquiry test was adapted from the view of nature of scientific inquiry questionnaire which was developed by Lederman and his colleagues. The test consisted of seven items in written open-ended format which allowed the students to express their own idea. The draft test was presented to the dissertation advisors and experts for the content validity check, accuracy of the test, appropriateness, precision, and wording. It was revised before using with the participants.

3) Nature of science Test

The Nature of science test was adapted from the view of nature of scientific inquiry questionnaire which was developed by Lederman and his colleague. The test consisted of seven items in written open-ended format which allowed the students to express their own idea. The draft test was presented to the dissertation advisors and experts for the content validity check, accuracy of the test, appropriateness, precision, and wording. It was revised before using with the participants.

4) Science attitude scale for middle school students

The Science Attitude Scale for Middle School Students (SASMSS) was developed by Frank L. Misiti, Robert L. Shrigley, and Lylee Hanson in 1991. There are 23 statements to assess students' attitudes toward science. The instrument was developed based on five point Likert scale questionnaire ranging from strongly agree, agree, undecided, disagree, to strongly disagree.

The instrument was translated and offered to dissertation advisors to check the appropriateness, ambiguity in language, and wording of the questionnaire. Trying out and revising the questionnaire to non-target students are needed before implementing to participants.

5.2 Research on students' ability to conduct scientific inquiry, understand of nature of scientific inquiry, and nature of science

The rapid cycling *Brassica rapa* activities were used in science classroom of 40 eighth grade students at Chaturatwittayakarn School during the second semester of the 2011 academic year. Data collection included pre-test and post-test of students' scientific inquiry skills, students' understanding of nature of scientific inquiry, and students' understanding of nature of science. The questionnaire of students' attitude towards science was used to collect after the implementation of activity. Classroom observation was documented by the researcher in order to gather qualitative data for the discussion of the result.

The *t*-test statistic was used to compare between pre-test and post-test of the students' scientific inquiry skills score, students' understanding of nature of scientific inquiry score, and students' understanding of nature of science score. It was also used to compare the student's mean score with criterion score and to indicate whether or not there was any significant difference between them.

6. Conclusion of research results

This section describes the result of Phase I and Phase II. Phase I was the results of developments of warm temperature adapted breeding pool (WTABP) of Wisconsin Fast Plants. Phase II was the results of the implementation of WTABP activity in class. The results included students' scientific inquiry skills, students' understanding of nature of scientific inquiry, students' understanding of nature of science, and students' attitude toward science.

6.1 The results of warm temperature breeding pool of rapid cycling *Brassica rapa* development

The Rapid Cycling *Brassica rapa* had been adapted to warm temperature of Thailand through the four experiments as reported in previous chapters. After the experiments, the results shown that the plants can grow in warm temperature of 22-32°C. Some characteristics of the plants had been changed such as the plants size was smaller (height), development of flower bud and its open time took longer, seeds shape was flat and its color was lighter, and its life cycle took longer than usual. However, the plants could tolerate warm temperature. The range optimum is 22-32°C as mentioned above. In conclusion, the plants could grow and reproduce in warm temperature of Thailand. Seeds were obtained through the four experiments.

6.2 The results of the implementation of WTABP activity

This section describes the results of the research on students' scientific inquiry skills, students' understanding of nature of scientific inquiry, students' understanding of nature of science, and students' attitude towards science. The details are as follows:

6.2.1 The results of students' scientific inquiry skills

Student' scientific inquiry skills mean score after the instruction using rapid cycling *Brassica rapa* activity was higher than before the instruction at the 0.05 level of significance. This means the students who had performed through the activity had significantly improved their scientific inquiry skills. Also, students' scientific inquiry skills mean score was significantly higher than the cutting score at the 0.05 level of significance. The results supported the first hypothesis.

6.2.2 The results of students' understanding of nature of scientific inquiry

Students' understanding of nature of scientific inquiry mean score after the instruction using rapid cycling *Brassica rapa* activity was higher than before the instruction at the 0.05 level of significance. This means the students who had performed through the activity had significantly improved their understanding of nature of scientific inquiry. Also, students' understanding of nature of scientific inquiry mean score was significantly higher than the cutting score at the 0.05 level of significance. The results supported the second hypothesis.

6.2.4 The results of students' understanding of nature of science

Students' understanding of nature of science mean score after the activity implementation was higher than before at the 0.05 level of significance. It means the students who had performed the activity of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* had significantly improved their understanding of nature of science. However, the students' understanding of nature of science mean score was lower than the cut-off score. It was not significantly different at 0.05 level of significance; therefore, the result did not support the third hypothesis.

6.3 The result of students' attitude towards science

The results showed that all aspects were favorable to students at a high level. Moreover, the overall of students' attitude toward science was at a high level.

The forth hypothesis stated that students' attitude towards science was at a high level. The mean score of student's attitude toward science was evaluated comparing with the criteria score. As stated in chapter 3, the score 3.51-4.50 is interpreted as a high level of attitude toward science. The total mean of students' attitude towards science is 4.11 which means the result supported the hypothesis.

7. Discussion

This research concerned with the development of warm temperature adapted breeding pool of rapid cycling *Brassica rapa* and used for scientific inquiry teaching in Thai science classroom. It was expected that the students who had performed through the rapid cycling *Brassica rapa* activity would be able to improve their scientific inquiry skills,

understanding of the nature of scientific inquiry, and understanding of nature of science. Moreover, the activity of rapid cycling *Brassica rapa* should encourage students' attitude towards science. From the expectation above, the research hypotheses were determined and tested. The research finding after the activity showed that students' score from scientific inquiry skills test, nature of scientific inquiry test, and the means score of science attitude scale were higher than the criterion scores. These results support the hypotheses. However, the score of nature of science after doing the activity was lower than the criterion score. The purpose of the following section is to discuss the results described above.

7.1 Discussion on the result of warm temperature breeding pool of rapid cycling *Brassica rapa* development

Wisconsin fast plants (Rapid Cycling *Brassica rapa*) had been bred by Professor Paul H. Williams at the University of Wisconsin—Madison. The plant have a short life cycle, grows fast, changes visibly every day, and also changes easily to environment. It can grow and reproduce at the range of optimum at 22-32°C. When the plants adapted to warm temperature of Thailand, its change in some aspects would be discussed below:

Development of flower bud and its open flower day

After it had been adapted to warm temperature, development of flower bud of Rapid Cycling *Brassica rapa* took longer than usual. It could be observed on day 8-9 instead of day 7. It might have been caused by heat. Angadi and colleagues (2000) stated that all *Brassica* species were most adversely affected by a heat stress of 35/15°C at the early flowering stage. Slowly flower bud development, its first flower open was also shifted out. Furthermore, the heat affected the plants life cycle.

Development of seed pod

Even though seeds were harvested, seed pods were shorter than usual. It means that high temperature also affected the development of seed pod. Angadi and colleagues (2000) indicated that the visual monitoring of flowers that opened during the imposition of high temperature treatments revealed that they did not produce any fertile pods. Thus, not only were reproductive parts affected by high temperature injury, but smaller pods.

The WTABP's life cycle

From the discussion mentioned above, the development of flower bud and its first open flower day took longer than usual. This led to the longer life cycle. The results of the last experiment showed that the life cycle of the plants was longer. It might have been caused by the heat treated through the four experiments. Rapid cycling *Brassica rapa* were well grown and developed at 22-26°C but yields were still obtained throughout the warm temperature. It means that the plants tried to adapt themselves in order to grow and develop in heat.

7.2 Discussion on the result of students' scientific inquiry skills

The research finding showed that the students' post-test mean score was significantly higher than the pre-test mean score. Moreover, the students' post-test mean score was also significantly higher than the cut-off score (criterion score) in all aspects of scientific inquiry skills including setting testable question, developing hypothesis formulation, defining variation, planning to collect and analyze data, and drawing conclusion.

The reason that might account for the improvement of student's scientific inquiry skills emerged from the characteristics of rapid cycling *Brassica rapa* activities that give the importance of doing science. The first three activities encouraged students to practice all aspects of scientific inquiry skills: setting testable question, developing hypothesis formulation, defining variation, planning to collect and analyze data, and drawing conclusion and the fourth was the open-ended inquiry. Students had a chance to take full responsibility for all aspects of the investigation. The activity involved students in formulating their own research question and hypothesis, developing procedures to answer their research questions, collecting and analyzing data, and using evidence to make their own conclusions. Students might take advantage from this process of scientific inquiry. Moreover, the first three activities provided for students might lead them to become familiar with the scientific inquiry before they did their own research. In addition, Rapid cycling *Brassica rapa* is changed visibly to environments; therefore, this changes may encourage student to make testable question and formulate a hypothesis easily and allowed students to repeat the scientific inquiry four times. This could make students improve their scientific inquiry skills as Zorfass (1998: 54-62) stated that to carry out research is not a one time experience. The active researcher does not engage in inquiry for a prescribed period of time and then stop. Instead, a search for knowledge raises new questions and identifies other areas to explore. Teaching science to children by engaging them to do the

investigation should be a continuous process. From one activity, they are engaged to do another one. These processes can contribute to scientific inquiry skills and understanding of science concepts and how science knowledge has been developed over time.

Several research studies in the past have reported the effect of using inquiry method in the science classroom. Elliott and colleague (2010: 15) reported that having students do authentic science practice, there would be a great likelihood that students would develop the type of skills that scientists believe are valuable to graduates wanting to pursue scientific careers. These skills include: an appropriation of the importance of asking questions, of being as open-minded as possible, an understanding of scientific reasoning, the skills become a life-long learner, an ability to evaluate sources of information, data gathering skills, and an objective, analytical way of thinking. Baker and Piburn's work is also a good example of using Rapid cycling *Brassica rapa* to develop students' scientific inquiry skill (Baker and Piburn. 1997). They used the plants to encourage students to develop a hypothesis and apply the scientific method in a field setting by having students work through the experiment in pairs. Their report supported the result of this study that students had an opportunity to set the hypothesis, collect their data, write individual scientific reports, and present their finding in class. Students had the opportunity to experience a long-term experiment and to develop the skills and understanding of scientific inquiry (Erdogan (2006: 3-7).

7.3 Discussion about the result of students' understanding of nature of scientific inquiry

The research finding indicated that the students' post-test mean score of understanding of nature of scientific inquiry was significantly higher than the pre-test mean score. Moreover, the students' post-test mean score was also significantly higher than the cut-off scores (criterion score). It means students came to understand how science knowledge is constructed.

Nature of scientific inquiry is one's view of the nature and rationale of the process through which that knowledge is constructed and justified. Its aspects are those that pertain most to the processes of inquiry, the "how" the knowledge is generated and accepted (Schwartz, Lederman, & Lederman. 2008: 3). Rapid cycling *Brassica rapa* activities allowed students to involve in doing authentic scientific science which they could obtain what nature of scientific inquiry is. When students learnt through the activity of fast plants, they were actively engaged in the construction of idea and explanations. Instead of

learning about science, they learnt by doing science. When students took on the role of scientists, they came to understand the very nature of scientific inquiry (National Research Council, 2000).

By participating in inquiry-based experiences, students made observations of the rapid cycling *Brassica rapa* which led them to ask questions about what they saw. They conceptualized possible explanations, or hypotheses for their questions, and gathered evidence that might lead them to favor one explanation over another. Ideally, they design experiments to answer their question, and to share their finding with their peers. Inquiry is often cyclical, with reflection on the experience sparking new question for new study (Strauss. 2011: 1).

In this study, the aspects of nature of scientific inquiry that students' mean score with highest increasing are the interpretation and acceptance of data of scientists, meaning of data in science, and what constitutes scientific activity, respectively. The interpretation and acceptance of data is how the data are collected and interpreted in light of a question and how questions and procedures influence finding through the lens of the scientists. If scientists work independently, different conclusions may be drawn from the same set of data because scientists may view the data differently, weighing more heavily one type of information over another, or putting the pieces together in a different way (Schwartz, Lederman, & Lederman. 2008: 17). Students seem to understand this aspect of nature of scientific inquiry after doing the investigation with the rapid cycling *Brassica rapa*. They showed their point of view of how scientist views their data in a different way depending on their culture and community. It might be the reflection of the three activities that they had done the same experiment in group but drawn the conclusion differently.

For the meaning of data in science, their mean score in this aspect of nature of scientific inquiry was also high. The rapid cycling *Brassica rapa* activities affected their understanding of what data are because they collected data in both qualitative and quantitative ones. From their reports, they showed the difference between data and evidence. They viewed data as information gathered from the experiments. Instead, the evidence was data that have been interpreted. Not all data are evidence.

To what constitute science activity, students' mean score of the post-test was also higher than the pre-test. Students showed an understanding that science is not just doing experiments but there are many alternative ways of studying science, for example, the repeated observation, identification of a pattern, and inferred correlation based on the

observation. The rapid cycling *Brassica rapa* activity focused on doing science as the experiments but each experiment involved qualitative data collected from the observation that students had to observe their plants every day. When they drew the conclusion, they used qualitative data with the quantitative one for making conclusions.

However, students' understanding of the scientific experiments meaning post-test score was lower than the pretest. Students might misunderstand that some scientific inquiry that made the conclusion from the observation and inferred correlation based on the observation were the experiments. Also, with the working together of the scientists make the same conclusion. Students obtained lower score of post-test because they thought that if scientists work together with the same question and procedure would lead to the same conclusion. None showed the idea that scientists may draw the different conclusion even though they work together. However, it is more likely to reach the same conclusion because the research group or community should have a common goal or shared perspective.

7.4 Discussion on the result of students' understanding of nature of science

The research finding indicated that the students' post-test mean score of understanding of nature of science was significantly higher than the pre-test mean score. However, the students' post-test mean score was lower than the cut-off score (criterion score). It means that doing experiments of rapid cycling *Brassica rapa* did not affect their understanding of nature of science. This result did not support the hypothesis. The reasons are described as follows:

Rapid cycling *Brassica rapa* activity did not affect students' understanding of nature of science. The activities were scientific experiments which are not enough for students to get the right idea on nature of science. Matson and Parsons (1998) indicated that an understanding of the process of science and an ability to do scientific inquiry were needed in order to understand nature of science. However, they reported that it is not sufficient. It is the same as Lederman's work which contends that nature of science should be taught, not simply left to emerge from any particular set of classroom activities. If students are expected to develop more adequate conceptions of the nature of science, then any cognitive objectives should be planned for, explicitly taught, and assessed (Lederman and Lederman (2004: 36-39). Moreover, they said that most students do not learn nature of science implicitly, simply by doing science activities. Rather, the aspects of nature of

science needed to plan to integrate into the lesson. The best way to do this is through reflective discussions elicited through careful questioning.

Schwartz, Lederman, and Crawford (2004) distinguish aspects of nature of science as follows: tentativeness, empirical basis, subjectivity, creativity, sociocultural embeddedness, observation and inference, and laws and theories.

1. Tentativeness – scientific knowledge is subject to change with new observation and with the reinterpretations of existing observation.

2. Empirical basis – scientific knowledge is based on and/or derived from observations of the natural world.

3. Subjectivity – science is influenced and driven by the presently accepted scientific theories and laws. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experience dictate what and how scientists conduct their work.

4. Creativity and imagination – scientific knowledge is created from human imaginations and logical reasoning based on observation and inference of the natural world.

5. Sociocultural embeddedness – science is a human endeavor and is influenced by the society and culture in which it is practiced.

6. Observation and Inference – Science is based on both observation and inference.

7. Laws and theories – Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

In this research finding, each aspect of nature of science was studied. The finding showed that even the result was not significantly different, students' understanding of nature of science mean score in some aspects increased such as role of observation and inference for the scientific explanation and role of creativity and imagination. Studying science through rapid cycling *Brassica rapa* activities allowed students to observe and make the inference. Also, they used their creativity and imagination during the experiments. This might be the reason of the increased mean score of these nature of science aspects.

However, students did not seem to understand that scientific models were constructed from the observation and inference. They made the conclusion that scientific model are the copy of the nature. They failed to understand that scientific model is an

inference that is not real or not an exact copy of nature. So, doing scientific inquiry with the rapid cycling *Brassica rapa* did not affect students' understanding of nature of science in these parts of observation and inference aspect. This led to the post-test mean score which was lower than the cut-off score-the criterion score. Doing scientific investigation for a short time is not enough for students to understand the nature of science. Nature of science in science instruction should be formal (Crowther, Lederman, & Lederman. 2005: 50-52). It means that teachers should provide explicit instruction on nature of science such as giving an historical perspective of the scientific ideas that came before it, and why they were rejected in favor of the currently accepted idea, which might help students to further understand the nature of science.

7.4 Discussion on the result of students' attitude towards science

The results showed that all aspects were favorable to students at a high level. Moreover, the overall of students' attitude toward science was at a high level as well. The total mean of students' attitude towards science is 4.11 which means the result supported the hypothesis. Since Rapid cycling *Brassica rapa* is suitable for doing science in the classroom, its characteristics are very interesting such as its small size and needing small space to grow, and developing faster than other kind of plants, changing visibly every single day, sensitivity to environment changes, short flowering time and rapid life. These characteristics of the plants may affect students' attitude toward science. Moreover, scientific activities allowed students to have more positive impression on science (Foley & Mcphee. 2008: 10). In order to improve students' attitudes toward science, Movahedzadeh (2011: 13-19) reported that students must be motivated to learn science. From the characteristics of rapid cycling *Brassica rapa* such as change visibly every single day and very sensitive to environments, this could motivate students to do science very well as stated in the results of this study.

In this research, students had a chance to think and act like scientists through rapid cycling *Brassica rapa* activities so that it is no doubt whether students' attitude toward science were at a high level after the implementation of scientific inquiry through the fast plants activities.

8. Recommendations

After the interpretation of results of the study, the following concern needs to be considered when teaching students scientific inquiry.

8.1 Recommendation on development of warm temperature adapted breeding pool of rapid cycling *Brassica rapa*

The special characteristics of rapid cycling *Brassica rapa* make it useful for scientific inquiry classroom but it grows and reproduce at the temperature of 22-26 °C. The plant was adapted to warm temperature in order to be used in Thai science classroom. Even though the plants can grow and reproduce in warm temperature of Thailand, it still needs to be continued in the experiment to have more tolerant plants that can better adapt themselves to the environment especially the warm temperature.

8.2 Recommendation for the use of rapid cycling *Brassica rapa* activity

The results of the research showed that the rapid cycling *Brassica rapa* activity positively influenced students' scientific inquiry skills, students' understanding of nature of scientific inquiry, and students' attitude towards science. Below are the recommendations after observation on students who enjoyed exploring the plants.

1) Recommendation of the use of rapid cycling *Brassica rapa* activity for science teachers

Since the plant activity affected students' scientific inquiry skills, students' understanding of nature of scientific inquiry, and their attitude towards science, it means that the characteristics of the plants could encourage students to do and learn science. The activity allowed students to practice scientific inquiry so that they would learn how to do science and increase their scientific inquiry skills as well. The activity can be added to elective science class or some topics of biology such as flowering plants. The plants are useful for teaching life cycle of flowering plants. Students can obtain both science contents and scientific inquiry skills. Moreover, because the plants, as mentioned before, change visibly each day and easily respond to environmental change, teachers can use this plant in their class to encourage students' curiosity for asking scientific questions. Therefore, teachers who are the operators of the science curriculum should be informed about this effective learning.

Furthermore, rapid cycling *Brassica rapa* can be used to teach several contents of biology such as growth, development, life cycle of flowering plants, ecology and environment, inheritance and genetics, and physiology. Teacher can use the plants in biology class for encouraging students in both knowledge contents and scientific inquiry.

Using the rapid cycling *Brassica rapa* in science classroom might lead students to have scientific mind. The plants are suitable for scientific inquiry activity. Students can do authentic inquiry with it. Students would have a chance to do and think like scientists. Students develop scientific mind as they use the processes of scientific inquiry to ask valid questions and to gather and analyze information through WTABP activities. They understand how to develop hypotheses and make predictions. They are able to reflect on scientific practices as they develop plans of action to create and evaluate a variety of conclusions. Students are able to demonstrate the ability to communicate their findings to others.

2) Recommendation on the use of rapid cycling *Brassica rapa* activity for school administrators

Growing the rapid cycling *Brassica rapa* needs proper laboratory and instruments such as light bank, soil, fertilizer, pot for growing, and others. All needed support from the administrators as other laboratories. The plants are getting familiar with warm temperature of Thailand. Schools could support the budget for the continued study. Students can take advantage of the study by involving in the study of adapting the plants. Once administrators provide support to using the plants, student can learn more scientific inquiry process, understand more the nature of science, and act like scientists.

3) Further study

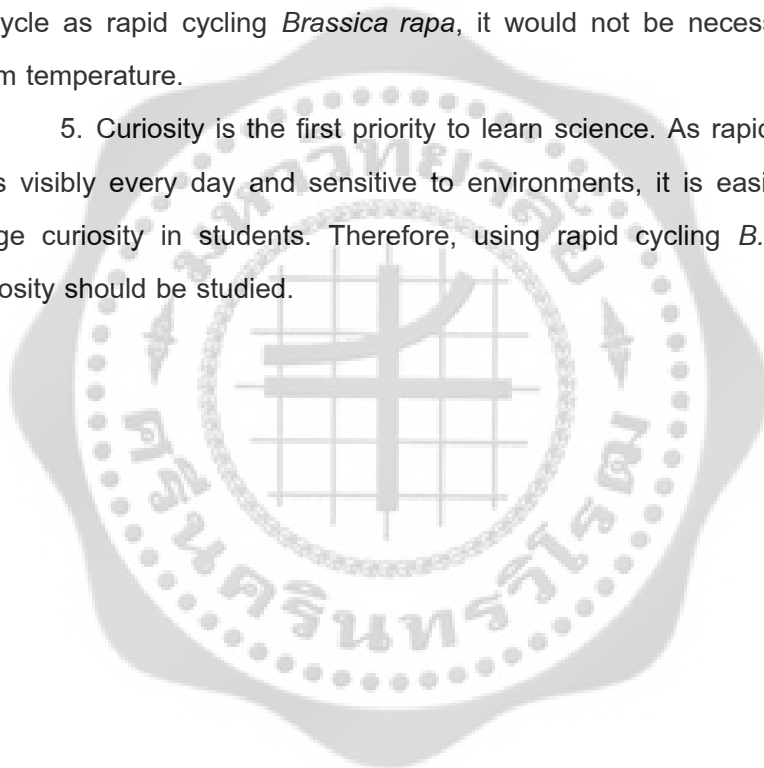
1. Rapid cycling *Brassica rapa* has special characteristics for teaching inquiry. The results of this study showed that the plants could adapt themselves to warm temperature of Thailand. It is inadequate for the plants to grow in the temperature above 35 degree Celsius. It should be studied more about how the plants adapt themselves to warm temperature.

2. Rapid cycling *Brassica rapa* supports inquiry instruction with high efficiency. It is a short life cycle plant so that it can be used for flowering plant life cycle teaching. Many of plant topics such as germination, reproduction, evolution can be taught using *B. rapa*. The study of achievements of biology content affected by rapid cycling *B. rapa* should be also studied.

3. Since the inquiry activity with rapid cycling *Brassica rapa* did not affect the students' understanding of nature of science, it should be more studied further on how to improve students' understanding of nature of science using rapid cycling *B. rapa* associated with, for example, history of some topics of Biology (history of photosynthesis study can be used). New activities should be created to study how students' understanding of nature of science will be improved.

4. Plants in Thailand should be selected and adapted in order to be suitable to Thai science classroom. There is no plant in Thailand that can be used to teach biology or scientific inquiry process in one time sowing. If we could find the plants that have a short life cycle as rapid cycling *Brassica rapa*, it would not be necessary to adapt the plants to warm temperature.

5. Curiosity is the first priority to learn science. As rapid cycling *Brassica rapa* changes visibly every day and sensitive to environments, it is easily observed. This can encourage curiosity in students. Therefore, using rapid cycling *B. rapa* to develop students' curiosity should be studied.





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APPENDIX





APPENDIX A

The list of experts

A list of the experts checking the quality of research tools

1. Dr. Kanchulee Punyain as an expert in science education
2. Dr. La-aw Ampornpan as an expert of plants
3. Mrs. Tasanee Man-A-pai as an expert of teaching science project
4. Miss. Orawan Man-A-pai as an expert of teaching science project
5. Mrs. Korapin Wongrattanachai as an expert of teaching science project and plants



APPENDIX B

The Results of Research Material Evaluation(In Thai)

ตาราง 1 ค่าความยากและอำนาจจำแนกของแบบทดสอบวัดทักษะการสืบเสาะทาง
วิทยาศาสตร์

ตาราง 2 ค่าดัชนีความสอดคล้องของรูปแบบการจัดการเรียนรู้แผนการสอนจากผู้เชี่ยวชาญ

ตาราง 3 ค่าดัชนีความสอดคล้องของแผนการจัดการเรียนรู้เรื่องการสืบเสาะหาความรู้ทาง
วิทยาศาสตร์ (คู่มือครู) จากผู้เชี่ยวชาญ

ตาราง 4 ค่าดัชนีความสอดคล้องของกิจกรรมการสืบเสาะหาความรู้ (คู่มือนักเรียน) จาก
ผู้เชี่ยวชาญ

ตาราง 1 ค่าความยากและอำนาจจำแนกของแบบทดสอบวัดทักษะการสืบเสาะทางวิทยาศาสตร์

ข้อที่	IOC	ค่าความยาก	ค่าอำนาจจำแนก
1	1.00	0.62	0.21
2	1.00	0.66	0.22
3	0.67	0.74	0.21
4	0.67	0.59	0.22
5	1.00	0.61	0.32
6	1.00	0.69	0.21

ค่าความเชื่อมั่นของแบบทดสอบวัดทักษะการสืบเสาะทางวิทยาศาสตร์เท่ากับ 0.80



ตาราง 2 ค่าดัชนีความสอดคล้องของรูปแบบการจัดการเรียนรู้แผนการสอนจากผู้เชี่ยวชาญ

ข้อที่	รายการประเมิน	ความคิดเห็นของผู้เชี่ยวชาญ			IOC
		คนที่ 1	คนที่ 2	คนที่ 3	
1	รูปแบบการจัดการเรียนรู้มีความสอดคล้องกับการจัดการเรียนรู้แบบสืบเสาะหาความรู้	1	1	1	1.00
2	วัตถุประสงค์ของการจัดการเรียนรู้มีความสอดคล้องกับรูปแบบการจัดการเรียนรู้	1	1	1	1.00
3	รูปแบบการจัดการเรียนรู้มีความเหมาะสมแก่การนำไปใช้	1	1	0	0.67
4	รูปแบบการจัดการเรียนรู้มีความสะดวกในการนำไปใช้	0	1	1	0.67
5	รูปแบบการจัดการเรียนรู้มีความชัดเจน	1	1	1	1.00
6	รูปแบบการจัดการเรียนรู้สามารถพัฒนาผู้เรียนตามหลักการเรียนรู้โดยใช้สมองเป็นฐาน	1	1	1	1.00
7	แต่ละขั้นตอนของรูปแบบการจัดการเรียนรู้ มีความสอดคล้อง	1	1	1	1.00

ตาราง 3 ค่าดัชนีความสอดคล้องของแผนการจัดการเรียนรู้เรื่องการสืบเสาะหาความรู้ทาง
วิทยาศาสตร์ (คู่มือครู) จากผู้เชี่ยวชาญ

ข้อที่	รายการประเมิน	IOC			
		แผนการเรียนรู้ที่			
		1	2	3	4
1	องค์ประกอบของแผนการจัดการเรียนรู้มีความสอดคล้องกัน	1.00	1.00	1.00	1.00
2	สาระสำคัญมีความชัดเจน	1.00	1.00	0.67	1.00
3	จุดประสงค์การเรียนรู้สอดคล้องกับคำอธิบายรายวิชา	1.00	1.00	1.00	1.00
4	เนื้อหาสอดคล้องกับจุดประสงค์การเรียนรู้	1.00	0.67	1.00	1.00
5	กระบวนการจัดการเรียนรู้สอดคล้องกับจุดประสงค์การเรียนรู้	1.00	1.00	1.00	1.00
6	สื่อและแหล่งการเรียนรู้เหมาะสมกับกระบวนการจัดการเรียนรู้	1.00	1.00	1.00	1.00
7	การวัดและประเมินผลสอดคล้องกับจุดประสงค์การเรียนรู้	1.00	1.00	1.00	1.00

ตาราง 4 ค่าดัชนีความสอดคล้องของกิจกรรมการสืบเสาะหาความรู้ (คู่มือนักเรียน) จากผู้เชี่ยวชาญ

ข้อที่	รายการประเมิน	IOC			
		กิจกรรมที่			
		1	2	3	4
1	องค์ประกอบของกิจกรรมมีความสอดคล้องกัน	1.00	1.00	1.00	1.00
2	สาระสำคัญมีความชัดเจน	1.00	1.00	1.00	0.67
3	จุดประสงค์การเรียนรู้สอดคล้องกับกิจกรรม	1.00	1.00	1.00	1.00
4	กระบวนการจัดการเรียนรู้สอดคล้องกับจุดประสงค์การเรียนรู้	0.67	1.00	1.00	1.00
5	สื่อและแหล่งการเรียนรู้เหมาะสมกับกระบวนการจัดการเรียนรู้	1.00	1.00	1.00	1.00

APPENDIX C

Sample of Research Instruments and tools

- 1. Views of Nature of Science: Elementary/Middle School Version (VNOS D)**
- 2. Views of Scientific Inquiry Questionnaire (VOSI)**
- 3. Scientific Inquiry Skills Test (แบบทดสอบวัดทักษะการสืบเสาะทางวิทยาศาสตร์)**
- 4. Science Attitude Scale for middle school students (แบบวัดเจตคติของนักเรียนที่มีต่อวิทยาศาสตร์)**

Views of Nature of Science:
Elementary/Middle School Version (VNOS D)

Name: _____

Grade: _____

Age: _____

Date: _____

Instructions

1. Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
 2. Some questions have more than one part. Please make sure you write answers for each part.
 3. This is not a test and will not be graded. There are no “right” or “wrong” answers to the following questions. I am only interested in your ideas about the following questions.
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1. What is science?

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2. How is science different from the other subjects you are studying?

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3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example

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4. How do scientists know that dinosaurs really existed?

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Views of Scientific Inquiry Questionnaire (VOSI)

Name: _____

Class: _____

Date: _____

The following questions are asking for your views related to science and scientific investigations. There are no right or wrong answers.

Please answer each of the following questions. You can use all the space provided to answer a question and continue on the back of the pages if necessary.

1. What types of activities do scientists (e.g., biologists, chemists, physicists, earth scientists) do to learn about the natural world? Discuss how scientists (biologists, chemists, earth scientists) do their work.

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2. How do scientists decide what and how to investigate? Describe all the factors you think influence the work of scientists. Be as specific as possible.

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3. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds who eat hard shelled nuts have short, strong beaks, and birds who eat insects from tide pools have long, slim beaks. He concluded that there is a relationship between beak shape and the type of food birds eat.

3.1 Do you consider this person's investigation to be scientific? Please explain why or why not.

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3.2 Do you consider this person's investigation to be an experiment? Please explain why or why not.

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แบบทดสอบวัดทักษะการสืบเสาะทางวิทยาศาสตร์

ชื่อ.....ชั้น.....เลขที่.....

1. นักเรียนคนหนึ่งทดลองปลูกผักบุงพร้อมกัน 2 กระป๋องโดยควบคุมสิ่งต่าง ๆ ให้เหมือนกัน เช่น ขนาดและจำนวนเมล็ดที่ใช้ปลูก ชนิดของดิน ภาชนะ ปริมาณน้ำที่ใส่รด เป็นต้น กระป๋องใบที่ 1 วางไว้ในที่มีแสงสว่าง ใบที่ 2 วางไว้ในห้องมืด เป็นเวลา 5 วัน จึงสังเกต และบันทึกผลการทดลอง

1.1 นักเรียนจะตั้งคำถามการทดลองว่าอย่างไร

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1.2 นักเรียนจะตั้งสมมติฐานการทดลองนี้ว่าอย่างไร

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1.3 การทดลองนี้ ตัวแปรอิสระคืออะไร

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2. นักธรณีวิทยาศึกษาภาพแผนที่โลกและทำการบันทึกว่า ชายฝั่งทางด้านตะวันออกของทวีปอเมริกาใต้และทวีปแอฟริกาสามารถต่อกันได้เกือบพอดี และยังพบว่ารอยโป่งทางด้านตะวันตกของแอฟริกาสามารถต่อเข้ากับรอยขอบทวีปช่วงอ่าวเม็กซิโกจนถึงตอนใต้ของทวีปอเมริกาเหนือ ดังนั้นเค้าจึงสรุปว่า ทวีปแอฟริกาและทวีปอเมริกาใต้เคยต่อเป็นทวีปเดียวกัน เมื่อหลายล้านปีก่อน หลักฐานทางวิทยาศาสตร์ใดบ้างที่สนับสนุนข้อสรุปดังกล่าวของนักธรณีวิทยา

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3. นักวิจัยทางการเกษตรคนหนึ่งต้องการศึกษาชนิดของปุ๋ยที่ส่งผลต่อการเจริญเติบโตของผักคะน้า นักเรียนจะช่วยนักวิจัยคนนี้ออกแบบการทดลองอย่างไร

3.1 นักเรียนจะตั้งคำถามการทดลองอย่างไร

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3.2 นักเรียนจะตั้งสมมติฐานการทดลองอย่างไร

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3.3 ตัวแปรการทดลองคืออะไร

ตัวแปรต้น

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ตัวแปรตาม

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ตัวแปรควบคุม

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3.4 นักเรียนจะออกแบบการทดลองได้อย่างไร

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3.5 ให้นักเรียนออกแบบตารางบันทึกผล

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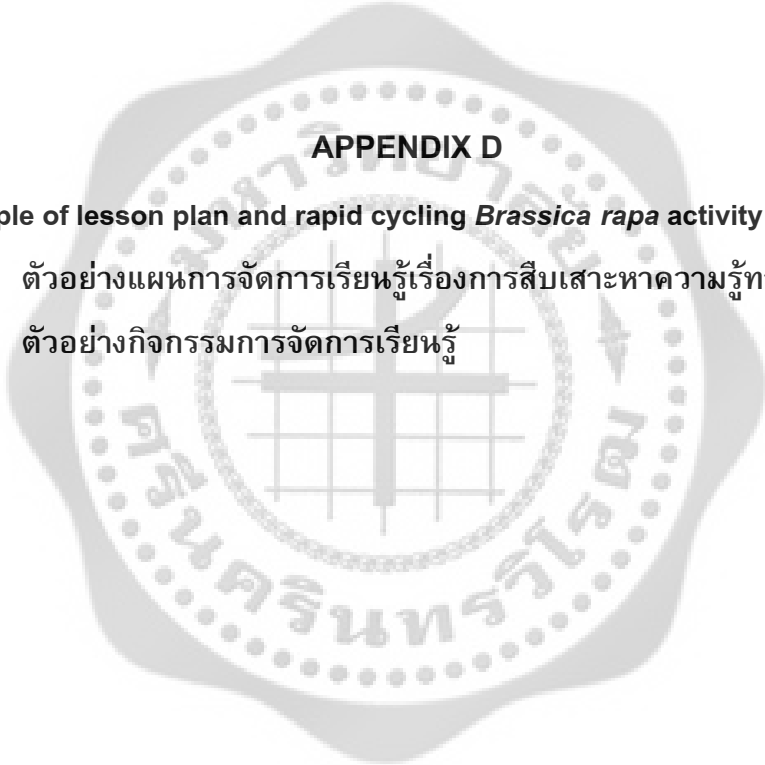
แบบวัดเจตคติของนักเรียนที่มีต่อวิทยาศาสตร์
Science Attitude Scale for middle school students

คำชี้แจง

ข้อความต่อไปนี้เป็นข้อความที่เกี่ยวกับเจตคติของนักเรียนที่มีต่อวิทยาศาสตร์ นักเรียนอาจเห็นด้วยหรือไม่เห็นด้วยกับข้อความเหล่านั้นก็ได้

ให้นักเรียนอ่านและทำความเข้าใจข้อความอย่างรอบคอบและตัดสินใจว่านักเรียนเห็นด้วยกับข้อความนั้นหรือไม่ จากนั้นนักเรียนสามารถทำเครื่องหมายลงในช่องเห็นด้วยอย่างยิ่ง เห็นด้วย ไม่แน่ใจ ไม่เห็นด้วย หรือไม่เห็นเห็นด้วยอย่างยิ่ง

ข้อความ	เห็นด้วย อย่างยิ่ง	เห็น ด้วย	ไม่ แน่ใจ	ไม่ เห็น ด้วย	ไม่เห็น ด้วยอย่าง ยิ่ง
1. การอ่านหนังสือวิทยาศาสตร์เป็นเรื่องน่าเบื่อ					
2. ฉันไม่ชอบการบันทึกข้อมูลการทดลอง วิทยาศาสตร์ลงในสมุดบันทึก					
3. ฉันรู้สึกไม่ชอบที่ต้องดูภาพยนตร์วิทยาศาสตร์					
4. ฉันภาวนาให้ถึงคาบเรียนวิชาวิทยาศาสตร์เร็ว ๆ					
5. ฉันไม่ชอบดูรายการเกี่ยวกับวิทยาศาสตร์ทางทีวี					
6. ฉันไม่ชอบวิชาวิทยาศาสตร์					
7. การเรียนรู้ความจริงทางวิทยาศาสตร์เป็นเรื่องที่ น่าเบื่อ					



APPENDIX D

Sample of lesson plan and rapid cycling *Brassica rapa* activity (In Thai)

1. ตัวอย่างแผนการจัดการเรียนรู้เรื่องการสืบเสาะหาความรู้ทางวิทยาศาสตร์
2. ตัวอย่างกิจกรรมการจัดการเรียนรู้

แผนการจัดการเรียนรู้เรื่องการสืบเสาะหาความรู้ทางวิทยาศาสตร์ ชั้นมัธยมศึกษาปีที่ 2
 หน่วยการเรียนรู้ที่ 1: การเตรียมความพร้อมก่อนการสืบเสาะหาความรู้ จำนวน 9 คาบ
 แผนการเรียนรู้ที่ 1: ขนาดของเมล็ดกับการเจริญเติบโตของพืชโตเร็ว จำนวน 3 คาบ

สาระสำคัญ

เมล็ดพืชโตเร็วมีขนาดแตกต่างกัน ความสามารถในการเจริญเติบโตของใบเลี้ยงและลำต้นในช่วงสัปดาห์แรกย่อมไม่เท่ากันเมื่อควบคุมการปลูกให้อยู่ในสภาพเดียวกัน

สาระที่ 8 ธรรมชาติของวิทยาศาสตร์และเทคโนโลยี

มาตรฐาน ว 8.1 ใช้กระบวนการทางวิทยาศาสตร์และจิตวิทยาศาสตร์ในการสืบเสาะหาความรู้ การแก้ปัญหา รู้ว่าปรากฏการณ์ทางธรรมชาติที่เกิดขึ้นส่วนใหญ่มีรูปแบบที่แน่นอน สามารถอธิบายและตรวจสอบได้ ภายใต้อข้อมูลและเครื่องมือที่มีอยู่ในช่วงนั้น ๆ เข้าใจว่าวิทยาศาสตร์ เทคโนโลยี สังคมและสิ่งแวดล้อม มีความเกี่ยวข้องสัมพันธ์กัน

จุดประสงค์การเรียนรู้

1. นักเรียนสามารถตั้งคำถามที่สามารถตรวจสอบได้
2. นักเรียนสามารถบอกตัวแปรอิสระ ตัวแปรตาม และตัวแปรควบคุมได้
3. นักเรียนสามารถออกแบบการทดลอง เก็บข้อมูล จัดกระทำข้อมูลได้
4. นักเรียนสามารถนำเสนอผลการสืบเสาะหาความรู้ได้

กระบวนการจัดการเรียนรู้

1. ขั้นสร้างความสนใจ

ครูให้นักเรียนสังเกตเมล็ดผักกาด (อาจใช้เมล็ดผักกวางตุ้งแทน) และให้นักเรียนบอกความแตกต่างของเมล็ด ครูเขียนข้อสังเกตเกี่ยวกับเมล็ดที่นักเรียนเสนอบนกระดาน เพื่อนำเข้าสู่การอภิปรายขนาดของเมล็ดมีผลต่อการเจริญเติบโตหรือไม่ เมื่อนักเรียนเสนอข้อสังเกตเสร็จแล้ว ครูนำอภิปรายถึงความแตกต่างของเมล็ดผักกาดที่สังเกตได้ภายนอก เช่น สี ลักษณะกลมมน แบน หรือมีขนาดแตกต่างกัน จากนั้นครูให้นักเรียนสังเกตเมล็ดพืชโตเร็วแต่มีขนาดเล็กและใหญ่ ครูตั้งคำถามว่า “ขนาดของเมล็ดมีผลต่อการเจริญเติบโตในช่วงอายุ 1-7 วันหรือไม่” นักเรียนรู้ได้อย่างไร

2. ขั้นสำรวจและสืบค้น

2.1 นักเรียนแบ่งกลุ่ม ๆ ละ 4-5 คน จากนั้นครูนำนักเรียนด้วยคำถาม “ถ้าใช้เมล็ดพืชโตเร็วที่มีขนาดต่างกันจะมีผลต่อการเจริญเติบโตของพืชโตเร็วในช่วงอายุ 1-7 วันหรือไม่”

2.2 ครูให้นักเรียนศึกษากิจกรรมที่ 1 ขนาดของเมล็ดกับการเจริญเติบโตของพืชโตเร็วอย่างละเอียด

2.3 จากกิจกรรมที่ 1 นักเรียนแต่ละกลุ่มจะต้องปฏิบัติดังต่อไปนี้

- ตั้งคำถามที่สามารถตรวจสอบได้ด้วยกระบวนการทางวิทยาศาสตร์ โดยศึกษาวิธีการตั้งคำถามที่สามารถตรวจสอบได้จากกิจกรรมเสริมเรื่อง “คำถามที่ตอบได้”
- การกำหนดตัวแปรอิสระ ตัวแปรตาม และตัวแปรควบคุม โดยศึกษาวิธีการกำหนดตัวแปรได้จากกิจกรรมเสริมเรื่อง “การกำหนดตัวแปร”
- ตั้งสมมติฐานและออกแบบการทดลองเพื่อทดสอบสมมติฐาน โดยศึกษาวิธีการตั้งสมมติฐานได้จากกิจกรรมเสริมเรื่อง “การตั้งสมมติฐาน”
- เขียนคำถามการทดลอง ตัวแปรการทดลอง และสมมติฐานที่กลุ่มกำหนดในคู่มือกิจกรรม

2.4 นักเรียนแต่ละกลุ่มรับเมล็ดพืชโตเร็วที่มีขนาดต่างกันที่ครูเตรียมไว้ และทำการปลูกเมล็ดพืชโตเร็วตามวิธีการที่แผนการทดลองกำหนด โดยระวังตัวแปรที่ต้องควบคุมให้คงที่

2.5 (นอกคาบเรียน) นักเรียนเก็บบันทึกข้อมูลของพืชโตเร็วทุกวัน ทั้งเชิงคุณภาพ เช่น สังเกตลักษณะสีของใบ กลิ่น รสชาติ และเชิงปริมาณ คือ ความสูง และความกว้างของใบเลี้ยง แล้วบันทึกลงในคู่มือกิจกรรม

หมายเหตุ สิ่งที่นักเรียนต้องปฏิบัติระหว่างการศึกษาเก็บข้อมูล ได้แก่

- สังเกตลักษณะการเจริญเติบโตของต้นพืชโตเร็วทุกวันทางด้านคุณภาพ
- วัดความสูงและความกว้างของใบเลี้ยงของพืชโตเร็วทั้งสองใบพร้อมบันทึกข้อมูลและนับจำนวนใบแท้ของพืชโตเร็ว
- แต่ละกลุ่มจัดทำข้อมูลพร้อมนำเสนอข้อมูลด้วยกราฟ นักเรียนอาจศึกษาวิธีการนำเสนอข้อมูลด้วยกราฟจากกิจกรรมเสริม “การนำเสนอข้อมูลด้วยกราฟ”

3. ขั้นตอนิบายและลงข้อสรุป

นักเรียนแต่ละกลุ่มอภิปรายและร่วมกันสร้างคำอธิบายจากการทดลอง ว่าขนาดของเมล็ดมีผลต่อการเจริญในช่วงสัปดาห์แรกของพืชโตเร็วหรือไม่ แต่ละกลุ่มนำเสนอข้อมูลที่จัดกระทำแล้วต่อชั้นเรียน เมื่อกลุ่มนำเสนอเสร็จเรียบร้อยแล้ว ครูนำอภิปรายความสัมพันธ์ของขนาดของเมล็ดกับความสามารถในการเจริญเติบโตของพืชโตเร็วในช่วงอายุ 1-7 วัน นักเรียนร่วมกันลงข้อสรุปอีกครั้ง

4. ขั้ขยายความรู้

- 4.1 แต่ละกลุ่มร่วมกันอภิปรายเปรียบเทียบเกี่ยวกับลักษณะอื่น ๆ ของเมล็ดพืชโตเร็ว เช่น สีที่แตกต่างกัน รูปทรงของเมล็ด และอื่น ๆ กลุ่มศึกษาองค์ประกอบของเมล็ดพืชทั้งด้านนอกและด้านในเมล็ด โดยใช้แว่นขยายส่องดูรายละเอียดเปลือกเมล็ด เอนโดสเปิร์ม ใบเลี้ยง และส่วนของเอ็มบริโอ ซึ่งประกอบด้วยรากแรกเกิด ไฮโพคอติล ยอดอ่อน
- 4.2 กลุ่มร่วมกันอภิปรายเกี่ยวกับพืชในตระกูลพืลโตเร็วที่พบในประเทศไทย ซึ่งได้แก่ คะน้า กวางตุ้ง ผักกาด กะหล่ำปลี กะหล่ำดอก เป็นต้น นักเรียนลองสังเกตเปรียบเทียบเมล็ดพืชดังกล่าวที่ครูแจกให้กับเมล็ดพืชโตเร็ว พร้อมกับบอกความแตกต่างทั้งภายในและภายนอก
- 4.3 แต่ละกลุ่มอภิปรายว่าเมล็ดพืชแต่ละชนิดมีองค์ประกอบภายในเหมือนกันหรือไม่ กลุ่มศึกษาองค์ประกอบของเมล็ดถั่วเขียวเปรียบเทียบกับเมล็ดข้าวโพด พร้อมอภิปรายสรุป
- 4.4 นักเรียนแต่ละกลุ่มอภิปรายและทดลองตั้งคำถามการทดลองเกี่ยวกับเมล็ดพืชที่นักเรียนได้สังเกตเมล็ดพืชชนิดต่าง ๆ

5. ขั้ประเมินผล

กลุ่มเขียนรายงานการทดลองส่งครู

สื่อและแหล่งเรียนรู้

1. คอมพิวเตอร์พร้อมอินเทอร์เน็ต
2. เมล็ดพืชโตเร็ว
3. อุปกรณ์การปลูกพืชโตเร็ว
4. อุปกรณ์ที่ใช้ในการสังเกตการเจริญเติบโตของพืชโตเร็ว เช่น ไม้บรรทัด แว่นขยาย

การวัดและประเมินผล

วิธีการวัดและประเมิน	เครื่องมือวัด	เกณฑ์การผ่าน
1. สังเกตการอภิปรายและการทำงาน กลุ่ม	แบบสังเกต	ร้อยละ 50
2. ตรวจเล่มรายงานการทดลอง	แบบตรวจเล่มรายงาน	ร้อยละ 50



บันทึกหลังการสอน

ด้านความรู้

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ด้านทักษะและกระบวนการ

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การทำงานเป็นกลุ่ม

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ปัญหาและอุปสรรค

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ข้อเสนอแนะ

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กิจกรรมที่ 1

ขนาดเมล็ดกับการเจริญเติบโตของพืชโตเร็ว

วัตถุประสงค์

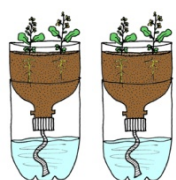
1. นักเรียนสามารถสรุปความสัมพันธ์ระหว่างขนาดเมล็ดกับความกว้างของใบเลี้ยงและความสูงของพืชโตเร็วในช่วงอายุ 1 – 7 วันได้
2. นักเรียนสามารถตั้งคำถาม กำหนดตัวแปร ตั้งสมมติฐานการทดลองได้
3. นักเรียนสามารถสังเกต เก็บข้อมูล จัดกระทำข้อมูล สรุปผลการทดลอง และนำเสนอผลการทดลองได้

อุปกรณ์

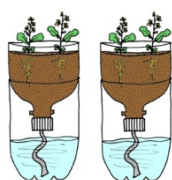
1. เมล็ดพืชโตเร็วขนาดใหญ่ กลาง และเล็ก
2. ดินสำหรับปลูก
3. ขวดน้ำพลาสติกขนาด 600 มิลลิลิตร
4. ด้ายที่ดูดซับน้ำได้ดี
5. ชั้นปลูกพร้อมหลอดไฟที่ให้ความเข้มแสงไม่ต่ำกว่า 200 ลักซ์
6. ปุ๋ยสูตร 20-20-20
7. น้ำ

วิธีการดำเนินกิจกรรม

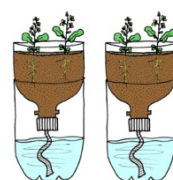
1. เตรียมเมล็ดที่มีขนาดต่างกัน 3 ขนาด คือ ใหญ่ เมล็ด และกลาง (ขนาดมาตรฐานซึ่งจะเป็นขนาดเปรียบเทียบ) อย่างละ 10 เมล็ด
2. เตรียมดินปลูกลงในภาชนะปลูก 6 ขวด แบ่งเป็น 3 กลุ่ม คือ สำหรับเพาะเมล็ดขนาดใหญ่ 2 ขวด สำหรับเมล็ดขนาดเล็ก 2 ขวด และสำหรับเมล็ดขนาดกลาง 2 ขวด
3. ปลูกเมล็ดขนาดใหญ่ ขนาดเล็กและขนาดกลางมาตรฐานลงในขวดปลูก ขวดละ 5 เมล็ด ดังภาพ



เมล็ดใหญ่



เมล็ดขนาดเล็ก



เมล็ดขนาดกลางเพื่อเปรียบเทียบ

4. ตั้งขวดปลูกไว้ที่ชั้นปลูก ให้แสงสว่าง 24 ชั่วโมง ความเข้มแสงไม่ควรต่ำกว่า 200 ลักซ์
5. สังเกตการงอกและการเจริญเติบโตของพืชโตเร็วที่ขวดปลูกทั้งเชิงคุณภาพ เช่น สีของลำต้น ลักษณะความสมบูรณ์แข็งแรงที่สามารถมองเห็นได้ด้วยตาเปล่า และเชิงปริมาณ เช่น วัดความสูง ความกว้างของใบเลี้ยง
6. วัดความสูงของพืชโตเร็วและความกว้างของใบเลี้ยงเมื่อพืชอายุครบ 4 วัน บันทึกผลลงในตารางบันทึกผล
7. สังเกตการเจริญเติบโตของพืชโตเร็วต่อและวัดความสูงของลำต้นเมื่อพืชอายุได้ 7 วัน (ควรสังเกตลักษณะทั่วไปของพืชเพื่อประกอบการสรุปและอภิปรายผล)
8. จัดกระทำข้อมูล นำเสนอข้อมูลโดยใช้ตารางหรือกราฟ และสรุปผลการทดลอง
9. เตรียมนำเสนอผลการทดลองและเขียนรายงานส่งครู

หมายเหตุ

ควบคุมชนิดและปริมาณดิน น้ำ และปุ๋ย ภาชนะปลูก อุณหภูมิ แสงสว่างให้คงที่

แบบบันทึกกิจกรรมที่ 1
ขนาดเมล็ดกับการเจริญเติบโตของพืชโตเร็ว

1. คำถามการทดลอง

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2. ระบุตัวแปรของการทดลอง

ตัวแปรต้น

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ตัวแปรตาม

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ตัวแปรควบคุม

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3. สมมติฐานของการทดลอง

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4. ผลการทดลอง

ตารางบันทึกความกว้างของใบเลี้ยง

ความกว้างของใบเลี้ยงจากเมล็ด พืชขนาดใหญ่ (cm)		ความกว้างของใบเลี้ยงจากเมล็ด พืชขนาดเล็ก (cm)		ความกว้างของใบเลี้ยงจากเมล็ด พืชขนาดกลาง (cm)	
ต้นที่ 1		ต้นที่ 1		ต้นที่ 1	
ต้นที่ 2		ต้นที่ 2		ต้นที่ 2	
ต้นที่ 3		ต้นที่ 3		ต้นที่ 3	
ต้นที่ 4		ต้นที่ 4		ต้นที่ 4	
ต้นที่ 5		ต้นที่ 5		ต้นที่ 5	
ต้นที่ 6		ต้นที่ 6		ต้นที่ 6	
ต้นที่ 7		ต้นที่ 7		ต้นที่ 7	
ต้นที่ 8		ต้นที่ 8		ต้นที่ 8	
ต้นที่ 9		ต้นที่ 9		ต้นที่ 9	
ต้นที่ 10		ต้นที่ 10		ต้นที่ 10	
เฉลี่ย		เฉลี่ย		เฉลี่ย	

อายุของพืชโตเร็ว

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ตารางบันทึกความสูงของพืชโตเร็ว

เมล็ดพืชขนาดใหญ่ (cm)		เมล็ดพืชขนาดเล็ก (cm)		เมล็ดพืชขนาดกลาง (สำหรับเปรียบเทียบ) (cm)	
ต้นที่ 1		ต้นที่ 1		ต้นที่ 1	
ต้นที่ 2		ต้นที่ 2		ต้นที่ 2	
ต้นที่ 3		ต้นที่ 3		ต้นที่ 3	
ต้นที่ 4		ต้นที่ 4		ต้นที่ 4	
ต้นที่ 5		ต้นที่ 5		ต้นที่ 5	
ต้นที่ 6		ต้นที่ 6		ต้นที่ 6	
ต้นที่ 7		ต้นที่ 7		ต้นที่ 7	
ต้นที่ 8		ต้นที่ 8		ต้นที่ 8	
ต้นที่ 9		ต้นที่ 9		ต้นที่ 9	
ต้นที่ 10		ต้นที่ 10		ต้นที่ 10	
เฉลี่ย		เฉลี่ย		เฉลี่ย	

อายุของพืชโตเร็ว

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5. อภิปรายและสรุปผลการทดลอง

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6. อุปสรรคและปัญหาที่พบขณะทำการศึกษา

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APPENDIX E

Sample of activity picture

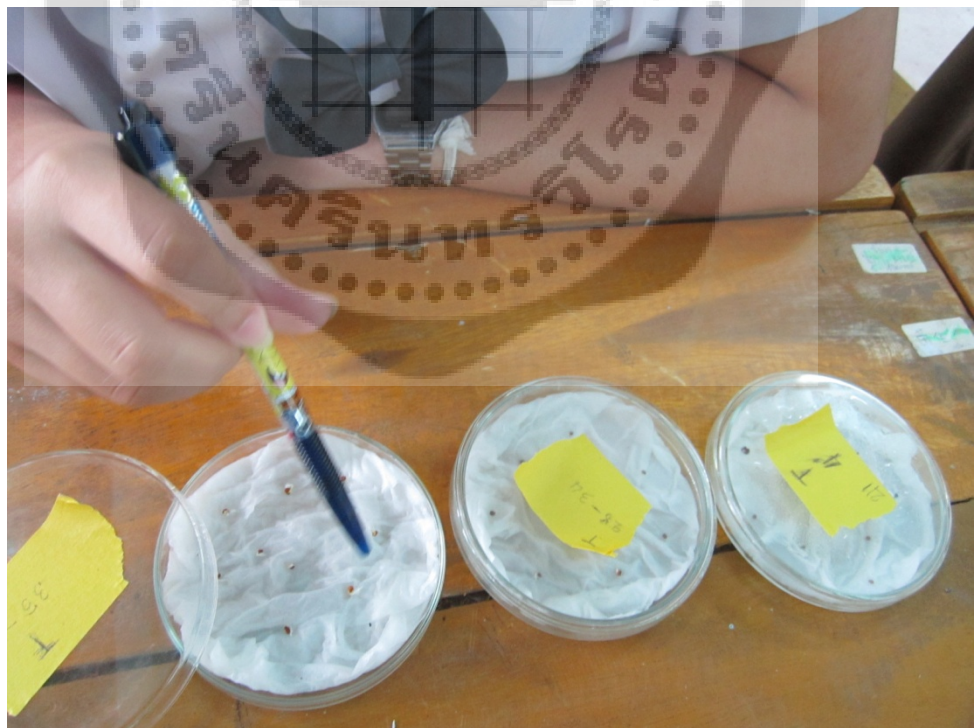




Students were collecting data



Students were preparing presentation



Students were doing their own activity



VITAE

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