A NOVEL LEARNING MODULE ON EARTHQUAKES BASED ON AN INQUIRY APPROACH

SUTTIDA RAKKAPAO

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (SCIENCE AND TECHNOLOGY EDUCATION) FACULTY OF GRADUATE STUDIES MAHIDOL UNIVERSITY 2010

Thesis
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ABSTRACT

The major goal of this research was to develop a new earthquake learning module based on an inquiry approach to promote Thai high school student understanding of earthquakes. The study has started from the identification the basic concepts of earthquakes from the standard curriculum of national education of Thailand in 2001. This module focused on the causes of earthquakes, exploring earthquakes in the world and in Thailand, seismic waves, the principle of seismographs, locating the epicenter, and the magnitude and intensity of earthquakes. Then, the open-ended questions were constructed to survey students' understanding of earthquakes. The questions were administered to 342 Thai students. The researcher analyzed the collected data to design a new learning module. Examples of teaching tools in this module were lesson plans based on the 5-E model of an inquiry method, a simple seismograph, a convection current demonstration set, and worksheets. Ultimately, the teaching tools of the module were validated by the statistical tests, modified by the experts' suggestions and tested with over 600 students, in order to reach the statistically reliable instruments.

This learning module was used with 245 tenth graders. It was evaluated through the students' conceptual understanding and satisfaction. Results revealed that this learning module can be much more effective than lecture-based teaching method in enhancing conceptual understanding of earthquakes, in particular, for science based program students, as indicated by the average of the normalized change ($\boldsymbol{c}_{\text{ave}}$). The $\boldsymbol{c}_{\text{ave}}$ was found to be 0.31. Moreover, more than 80% of these students agreed that this module facilitated their learning about earthquakes.

KEY WORDS: LEARNING MODULE/ EARTHQUAKES / INQUIRY / SEISMOGRAPHS /CONVECTION CURRENT

167 pages

ชุดการเรียนรู้แบบใหม่ตามกระบวนการสืบเสาะหาความรู้ เรื่องแผ่นดินไหว

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บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้คือการสร้างชุดการเรียนรู้แบบใหม่เรื่องแผ่นดินไหว เพื่อเพิ่มความเข้าใจของนักเรียนไทยระดับมัธยมศึกษา โดยอาศัยกระบวนการสืบเสาะหาความรู้ ผู้วิจัยเริ่มต้นจากการศึกษาสาระสำคัญเรื่องแผ่นดินไหวตามหลักสูตรการศึกษาขั้นพื้นฐาน พุทธศักราช 2544 กลุ่มสาระการเรียนรู้วิทยาศาสตร์ สาระที่ 6 กระบวนการเปลี่ยนแปลงของโลก ชุดการสอนแบบใหม่นี้มีเนื้อหาครอบคลุมสาระสำคัญได้แก่ สาเหตุการเกิดแผ่นดินไหว, การสำรวจแนวแผ่นดินไหวของโลกและประเทศไทย, คลื่นแผ่นดินไหว, หลักการของเครื่องวัดแผ่นดินไหว, การหาตำแหน่งจุดเหนือศูนย์เกิดแผ่นดินไหว, และมาตราวัดขนาดและความรุนแรงแผ่นดินไหว จากนั้นผู้วิจัยสร้างคำถามปลายเปิดเพื่อสำรวจความเข้าใจของนักเรียนเกี่ยวกับแผ่นดินไหว คำถามนี้ใช้เก็บข้อมูลกับนักเรียนจำนวน 342 คน ผู้วิจัยวิเคราะห์ข้อมูลที่ได้และนำไปใช้ประกอบการสร้างสื่อการสอนในชุดการเรียนรู้แบบใหม่นี้ ตัวอย่างสื่อการสอนที่ผู้วิจัยพัฒนาขึ้น เช่น แผนการเรียนรู้ที่อาศัยรูปแบบ 5-E ของกระบวนการสืบเสาะหาความรู้, แบบจำลองเครื่องวัดแผ่นดินไหวอย่างง่าย, ชุดสาธิตวงจรถ่ายเทความร้อน, ใบความรู้และใบงาน สื่อการสอนเหล่านี้ได้รับการประเมินจากทั้งผู้เชี่ยวชาญ และการนำไปทดลองใช้กับนักเรียนกว่า 600 คน เพื่อปรับปรุงให้มีประสิทธิภาพมากขึ้น

ผู้วิจัยนำชุดการเรียนรู้นี้ไปใช้สอนนักเรียนจำนวน 245 คน เพื่อประเมินคุณภาพโดยการประเมินความเข้าใจด้านเนื้อหาและความพึงพอใจของนักเรียนต่อชุดการเรียนรู้ พบว่า การสอนโดยใช้ชุดการเรียนรู้แบบใหม่เรื่องแผ่นดินไหวที่ผู้วิจัยสร้างขึ้นนี้ ทำให้นักเรียนมีการเรียนรู้เพิ่มขึ้นมากกว่าการสอนแบบบรรยายเป็นหลัก (c_{ave} เท่ากับ 0.31) และนักเรียนกว่า 80 เปอร์เซนต์พึงพอใจและเห็นด้วยว่าชุดการเรียนรู้นี้ช่วยให้เข้าใจเรื่องแผ่นดินไหวเพิ่มขึ้น

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CHAPTER I
INTRODUCTION

The dissertation introduction addresses a presentation of an importance for doing this research to promote Thai students' understanding of earthquakes. An overview of standard instructions of earthquakes in Thai high school levels and a new idea for construction the earthquake learning module based on the inquiry approach are discussed. Ultimately, the chapter provides the purposes of this study, research questions, and the scope of the research.

1.1 Context of the Study

The education of earthquakes at high school levels in Thailand was officially started in 2001. The earthquake topic was included in the 6^{th} strand of core concepts of sciences for Thai high school students following the standard curriculum of the national education Buddhist Era 2544. Its goals are to promote student comprehension of earthquakes and to increase their awareness about the consequence of earthquakes. The basic concepts of earthquakes in the curriculum comprise focuses, epicenters, faults, causes of earthquakes, both plate tectonic and human activities, Richter magnitude and modified Mercalli intensity scales, seismic waves, seismographs, histories of earthquakes in Thailand, Tsunamis, and safety procedures from earthquakes and their effects (IPST, 2008).

An earthquake is the vibration within the earth caused by the rupture and a sudden movement of plates that have been strained beyond their elastic limit (Richter, 1958; Lillie, 1999; Bolt, 2004). It is an evidence of the moving plates of the earth. Its consequences sometimes cause natural disasters, which people can confront. The historical records showed that during the last decade earthquakes have killed thousands of people and cost millions of dollars in damages around the world (USGS, 2009; Bolt, 2004; IRIS, 2009). In a year, there are more than one million earthquakes around the world, but most are the small magnitudes of earthquakes (NRC, 2008).

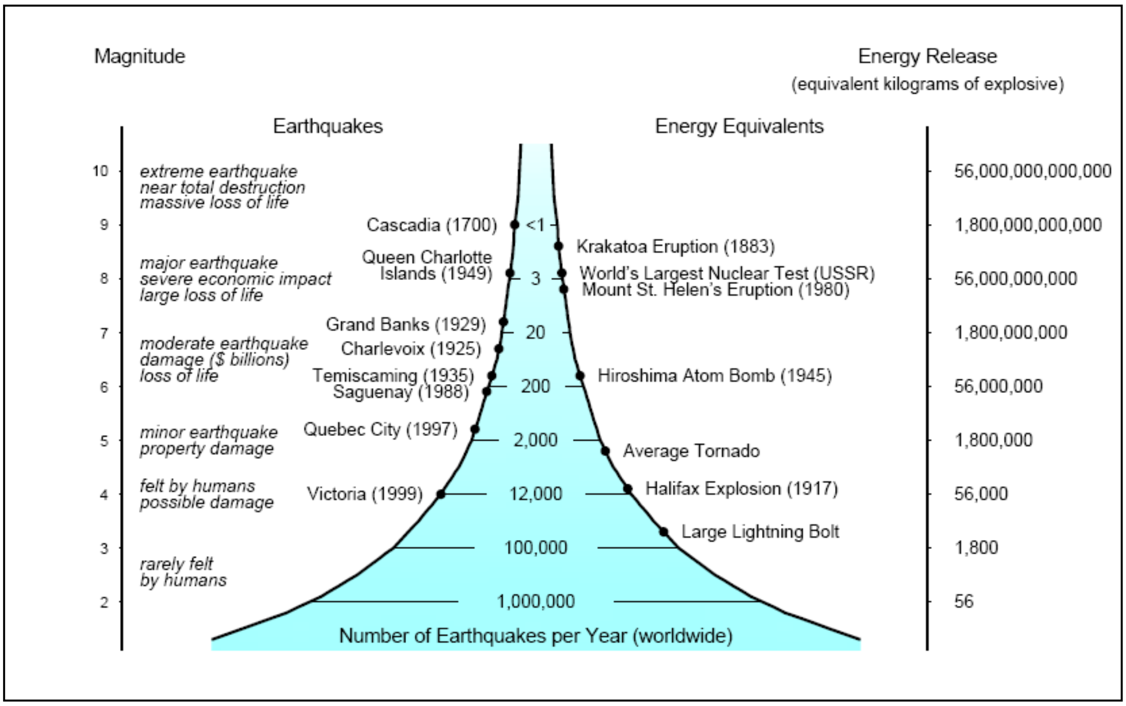


Figure 1.1: The relation of the frequency, magnitude and energy of worldwide earthquakes per year (take until 2003) (NRC, 2008)

Figure 1.1 illustrates the relation between the magnitude and the frequency of earthquakes around the world. The smaller the magnitudes of earthquakes are, the larger the number of earthquakes appears. The scale on the right hand side represents the amount of high explosives required to produce the equivalent energy released by such earthquakes. This suggests that the large number of the small magnitudes of earthquakes generates very low released energy, which has a small effect to the earth, as well.

Although Thailand is located on a low-intermediate seismic risk zone, Thai people have experienced some natural earthquake hazards (DMR, 2008). Thailand is located on the Eurasian plate surrounded by the Indo-Australian plate and the Pacific plate. In Thailand, there are at least 15 major active faults, where can be triggered to generate natural earthquakes (Kosuwan et al., 2008). The largest earthquake in

Thailand was a 6.5 magnitude quake occurring in 1935, and the epicenter was at the Pua fault zone, in the northern part of the country. In the previous three decades, there were 8 earthquakes in Thailand, with Richter magnitude greater than five. There are many small magnitudes of earthquakes in Thailand every year. Importantly, an unforgettable experience of Thai people in the Great Sumatra-Andaman Earthquake disaster of 26 December 2004 is known as the Asian Tsunami or the Boxing Day Tsunami (Lay et al., 2005; Maggie, 2005). Therefore, it is necessary for Thai students to have enough background knowledge about earthquakes in order to increase their awareness of the events.

Earthquakes are new topics not only for Thai high school students but also for teachers. The interview results showed that, in general, the standard instructions of the earthquake topics of Thai teachers were such as traditional lecture, lecture with passive demonstration via internet animations, cookbook experiments, and student presentations. In addition, the preliminary research revealed that most Thai high school students still held alternative concepts of earthquakes after the standard instructions. For example, they believed that earthquakes occur in rainy areas more than in dry areas. They also believed that the earthquake occurrence depends on the difference of topographies and earthquakes often happen near the islands (Rakkapao et al., 2007). Some students believed that all earthquakes damage manmade structures. About the seismic waves, these students believed that a medium’s particle will spread in all directions when P-waves arrive in the horizontal surface (Rakkapao et al., 2009). These students’ alternative conceptions indicated that the conventional teaching methods of earthquake at high school levels in Thailand need the improvement.

Therefore, to help Thai high school students to master knowledge and skills on their own, as well as the aim of encouraging them to think like scientists about authentic problems of earthquakes, the researchers have developed a new learning module based on the inquiry approach, which is an active learning method of the constructivism. This learning module focuses on giving an opportunity for students to complete activities on their own or in groups. It facilitates students to create their own concepts about earthquakes. In particular, this module promotes students to apply what they have learned to real life situations.

1.2 Purposes of the Study

The objectives of this study are;

(1) to identify the basic concepts of earthquakes for Thai high school students,

(2) to explore the high school students' alternative concepts of earthquakes, and

(3) to increase high school students' conceptual understanding of earthquakes by using a new learning module based on an inquiry approach.

1.3 Research Questions

To carry out the purposes of the study, the research questions will be responded.

(1) What are the basic concepts of earthquakes for Thai high school students?

(2) What are Thai students' alternative concepts of earthquakes?

(3) Does the new learning module (based on an inquiry approach) increase high school students' conceptual understanding of earthquakes?

1.4 Summary

This dissertation provides research data about teaching and learning earthquakes in Thailand, in particular, for high school students. The study addresses a new earthquake learning module based on an inquiry approach. It consists of 6 main chapters as following;

Chapter I: Introduction—the significance of this research, motivation and the aim of the research study,

Chapter II: Literature Review—research of alternative concepts of earthquakes, research of earthquake teaching and learning, the inquiry-based learning, the Geoscience Concept Inventory (GCI) and the normalized change, Chapter III: Development the Earthquake Learning Module— how to construct and evaluate the new learning module,

Chapter IV: Results,

Chapter V: Discussion, and

Chapter VI: Conclusions.

We hope that this research is of benefit to everyone, in particular, Thai teachers who are interested in the earthquake teaching and learning.

CHAPTER II
LITERATURE REVIEWS

This chapter presents the review of the literature, which guide what and how we should do to accomplish the objectives of this research. Four major topics are discussed here. Firstly, we will start from the demonstration of the previous researches reported alternative concepts of earthquakes. Secondly, we will present what other educators have done on earthquake teaching in the research of earthquake teaching and learning. Thirdly, the theoretical background, such as the constructivist theory and an inquiry-based learning approach, will be discussed. Finally, we will introduce the Geoscience Concept Inventory (GCI), and the normalized change.

2.1 Research of Alternative Concepts of Earthquakes

The previous studies of the earthquake comprehension have identified several significant alternative concepts. The followings are some of them held by both teachers and students.

In 1987, Leather found that over 50%, out of two hundred, of the 11-14 year old students in England participated in his study, believed that earthquakes occurred only in hot countries and those earthquakes were caused by heat. This is consistent with the results from Sharpe and others (1995), which conducted informal interviews with nine to ten year old students in Devon, England about causes of earthquakes. They found that these students believed that earthquakes occurred mostly in hot countries and were caused by heat inside the earth.

Furthermore, Ross and Shuell (1993) found that students have trouble understanding about the natural causes of earthquakes. Very few students considered plate movement to be a cause of earthquakes. Students thought that core movement, pressure, and volcanoes caused earthquakes. In addition, some students believed that heat from the sun on the earth, thunder, rain, wind, and mountains caused earthquakes.

Similarly, Libarkin and others (2005) found that although most college students could answer the term “plate tectonics or faults” when being asked to describe the cause of earthquakes, they were unable to explain the meaning of these terms when probed by interviews.

Correspondingly, Barrow and Haskins (1996) examined 186 college students understanding of earthquakes by using an open-ended questionnaire. The results indicated that students had limited knowledge about the theory of plate tectonics. These students believed that theory of plate tectonics was that “continents are not moving”. Moreover, the students were not aware of the relationship between earthquakes and tectonic activities.

In Taiwan, Tsai (2001) interviewed groups of the fifth and the sixth graders (eleven to twelve year olds) who had experienced on a serious earthquake in Taiwan in 1999. His study showed that some students believed that the occurrence of earthquakes involved with electromagnetic waves. Moreover, some students said that when ghosts were angry; they generated earthquakes.

Philips (1991) examined a list of over 50 earth science misconceptions among K-12 students, college students, and adults. Results indicated that adults and college students held the idea that “Chicago could not be severely damaged by an earthquake in the near future.” However, throughout history severe earthquakes have occurred in Chicago. This belief revealed the misconception about the causes of earthquakes. Similarly, Schoon (1989) conducted a wide-ranging study in the United States involving over 1200 undergraduates and school children aged five to eighteen. He found that 36% of these students thought Chicago was unlikely to be affected by an earthquake. Moreover, fifteen percent of them believed that earthquakes could be predicted accurately by observing the behavior of wild animals.

Not only students, but teachers also held alternative concepts about the causes of earthquakes. This is evident by the study of Monastersky (1992). He reported about teachers’ misconceptions of the causes of earthquakes in Science News from the study of Katharyn E. K. Ross and Andrea S. Dargush of the National Center of Earthquake Engineering Research in Buffalo, New York. They surveyed 45 elementary and secondary teachers. They addressed that 31% of these teachers believed that earthquakes occurred because the earth’s core moved to the surface. In addition, Oguz (2005) compared American and Turkish middle school students' existing knowledge of earthquakes by surveying via a systematic network. The participants were 823 students in the 5^{th} through the 8^{th} grades. Overall, he found that students from both countries held some alternative concepts about earthquakes. For instance, students believed that earthquakes were caused by the deep noises coming under the ground and bad vibrations. Students thought that animals have sense about earthquakes. Moreover, over half of the students in both countries did not know about earthquake safety. This study found that students who had experienced on a real earthquake did not have better knowledge about it.

Additionally, previous research has identified students' alternative concepts about earthquake locations, magnitude and intensity. For example, Whitney and others (2004) found that some students erroneously believed that earthquake occurrence could be easily predicted by unusual animal behavior or changes in weather. Oberhofer (1991) found that students commonly believed that a change of one magnitude on the Richter scale corresponds to a difference in released energy of 10 times (e.g., a difference of two magnitudes would be 100 times more energy). These students focused on orders of magnitude, instead of seismic energy; it was unclear whether students recognized a difference between magnitude and energy of the earthquakes.

Moreover, Oliver and Hannafin (2001) found that students often have trouble in earthquake engineering classes because these students did not know how seismic waves travel through the ground. Rakkapao and others (2009) reported that some Thai university students still had difficulty about the particle motion at the P-waves arrival. These students believed that particles spread in all directions, like water waves, when P-waves arrived. Moreover, some believed that particles moved forward with a sine wave motion, and that these particles traveled with the propagating wave energy to the P-wave's final destination.

In addition, Marques and Thompson (1997) explored the misconceptions of Portuguese students aged sixteen to seventeen. They reported that these students thought that volcanoes and earthquakes were quite familiar and earthquakes were mainly caused by volcanic activity. Happs (1982), in a study of eleven to seventeen year old students in New Zealand about the knowledge of mountains, found that some students believed that mountains could become volcanoes if they were shaken by earthquakes.

Collectively, table 2.1 summarizes these alternative concepts of earthquakes, based on their key ideas.

Table 2.1: Alternative concepts of earthquakes and the references

Alternative Concepts	References
Causes of Earthquakes	
Earthquakes occur only in hot countries.	Leather, 1987; Sharpe et al., 1995
The core movement causes earthquakes.	Monastersky,1992; Ross & Shuell, 1993
Earthquakes occur when the sun heats the earth's surface, causing cracks.	Leather, 1987; Ross & Shuell, 1993
Heat from the sun on the earth, thunder, rain, wind, and mountains cause earthquakes.	Ross & Shuell, 1993
Earthquakes are caused by the deep noises coming under the ground and earthquakes are caused by bad vibrations.	Oguz, 2005
The main causes of earthquakes are volcanic activities.	Leather, 1987; Marques & Thompson, 1997; Sharpe et al., 1995; Ross & Shuell,1993
Earthquakes come from a radical change of gravity. The cause of earthquakes involves with electromagnetic waves. When ghosts are angry, they generate earthquakes.	Tsai, 2001
Chicago is unlikely to be affected by an earthquake.	Philips, 1991; Schoon, 1989

Alternative Concepts	References
Plate Tectonic and Earthquakes	
Students do not aware of the relationship between earthquakes and tectonic activities.	Barrow & Haskins, 1996; Libarkin et al., 2005
Seismic Waves	
Students have low understanding of how seismic waves travel through the ground.	Oliver & Hannafin, 2001
Students believe that the medium particles spread in all directions when P-waves arrive. Moreover, some believe that particles move forward with a sine wave motion, and that these particles travel with the propagating wave energy to the P-wave's final destination.	Rakkapao et al., 2009
Others	
Earthquakes can be predicted accurately by observing the behavior of animals.	Oguz, 2005; Schoon, 1989; Whitney et al., 2004
A change of one magnitude on the Richter scale corresponds to a difference in released energy of 10 times.	Oberhofer, 1991
Mountains can become volcanoes if they are shaken by earthquakes.	Happs, 1982

2.2 Research of Earthquake Teaching and Learning

The effective teaching processes or tools for earthquakes have been proposed by various educators. Here are some examples.

In 2001, Hodder has studied about the effectiveness of a cooperative learning on the topic of earthquakes. He used the earthquake exercise as a quantitative measurement instrument. This involves the ranking of twelve action steps for survivors of a large earthquake who were trapped in the basement of a damaged multi-storey office building. There were 281 sophomores on the earth's resources and hazards course participating in this research. The comparison of the correct answers between individual and team groups showed that most groups have higher score than that of individual in the same group.

Carrington (1994) suggested that teachers could use the earthquake events, such as "The Northridge earthquake" as a tool for teaching in high school classroom. The interesting topic was not only the dynamics of earthquakes, also the resonance and wave interference. This was supported by Feldman (2004), who proposed "The 1989 Loma Prieta earthquake" in his earthquake class and found the positive feedback from the students.

Correspondingly, from the benefits of the internet; Butler and MacGregor (2003) suggested the instruction by using the near-real-time international information of earthquake, provided by the U.S. Geological Survey, in particular. Students could use the online data to plot the positions and sizes of earthquakes on the world map, to investigate the remarkable feature of worldwide earthquakes. Similarly, Gerencher Jr. and Sands (2004) reported that any classroom could freely download or run the near-real-time seismic traces from the software system called the Seismic Internet Monitoring Application (SIMA) for educational objectives via the internet. Classrooms could learn from the online seismograms. Moreover, teachers could use the signals from three or more servers to locate earthquake epicenters.

On the other hand, simple seismometers or seismographs also were constructed to enhance student understanding of earthquakes. This started from the idea of Walker (1979). Walker described a way to build a simple seismograph to record earthquake waves at home. His report said about an apparatus built by James D. Lehman, which was sufficiently sensitive to record North American earthquakes of magnitude 4.8 or more on the Richter scale and earthquakes magnitude 6 or more elsewhere. This simple seismograph could record the result of a nuclear test in Nevada, and a severe earthquake in Turkey at that time. Lehman's seismograph was a horizontal direction apparatus, which showed output by the drawing of a pen on a rotated paper (called seismogram). Lehman's seismograph was a pioneer of simple seismographs and well-known up to date. By modifying of this instrument, Barker (1987) constructed a Lehman seismograph and interfaced with a computer for using in the classroom. His students could use the seismograms to calculate the location of earthquakes. The studies, which involved the using of simple seismometers in classroom, were kept on (Averill, 1995; Braile, 2000; Kroll, 1987; Mims, 1991).

Many researchers have suggested the active-based activities for earthquakes in classrooms. These included experiments, hands-on activities, and interactive demonstrations. For instance, Hall-Wallace (1998) has developed an open-ended activity to promote students' understanding of the difficulty of earthquake prediction and the complex behavior of the earth systems. He engaged his students (the secondary school science teachers and students in USA) to design an experiment that modeled fault behavior and to determine which variables in the earth might affect the amount or magnitude of earthquakes that occurred. The activity focused on working as groups and the investigation by guided few key questions.

Fazio and others (2003) constructed an activity-based teaching unit that aimed to improve understanding of characteristics of earthquakes. It focused on analyzing the properties of very small earthquakes produced through mechanical shock waves in slabs of different materials. This activity-based teaching unit consisted of the topic of origin of earthquakes, Mercalli and Richter scales, finding earthquake epicenter by triangulation, earthquake prediction and prevention and seismic waves. Espinoza (2000) has developed the hands-on exploration activity for earthquakes in high school levels. This activity focused on the improving of both students' understanding of P-waves and S-waves time difference and the graph skill. Hubenthal and others (2008) have developed the Earthquake Machine Lite (EML) to benefit students' understanding of earthquakes, in particular, the causes of earthquakes, the distribution of positions and sizes of earthquakes, and earthquake prediction.

The other studies were such as Tuike (2001) used the slinky and shock wave animations to demonstrate the seismic waves in his classes. Goto (2002) developed the seismic wave demonstration set from the cotton buds, glue and sewing elastic for high school students.

Table 2.2 summarizes the teaching processes and tools of earthquakes, which have been reported, based on their categories.

Table 2.2: Teaching processes and tools of earthquake education

Teaching Processes or Tools	References
A Cooperative Learning	Hodder, 2001
Earthquake News	Carrington, 1994; Feldman, 2004
Online Earthquake Data Provided by Educational Website	Butler et al., 1996; Gerencher Jr. & Sands, 2004; Murfin, 1998
Simple Seismographs/Seismometers	Averill, 1995; Barker, 1987; Braile, 2000; Hubenthal, 2008; Kroll, 1987; Mims, 1991; Walker, 1979
Activity-Based Teaching	Espinoza, 2000; Fazio et al., 2003; Hall-Wallace, 1998; Hubenthal et al., 2008
Simple Apparatuses for Seismic Wave Demonstrations	Goto, 2002; Tuike, 2001

2.3 Theoretical Background

2.3.1 Constructivist Theory

Constructivist theory is a learning theory based on observations and scientific studies about how people learn. The outstanding features of the constructivism are; learning is active and learning is the interaction of the ideas and process. The new knowledge comes from the prior knowledge. Learning is enhanced when situated in contexts that students find familiar and meaningful. This indicated that students constructed their own understanding and knowledge of the world through their prior knowledge. When they find something new, they will integrate it with their previous ideas and experiences. They may change what they have believed, or may cancel the new information as irrelevant. Overall, it means that knowledge can not be taught, but constructed (Bransford et al., 1999; Bybee, 2002; Kim, 2005). Examples of famous pioneers of this learning theory are such as *Giovanni Battista (Giambattista) Vico (1668-1744)*, an Italian philosopher, who presented the well-known work as a "Science of Reasoning". *Immanuel Kant (1724-1804)* is a Russian philosopher who constructed "Critique of Pure Reason"—an investigation into the limitations and structure of reason itself. An American philosopher, *John Dewey (1859-1952)* was considered a pragmatist or instrumentalist. *Jean Piaget (1896-1980)* was a Swiss natural scientist and his well known works is about the studying in children. *Lev Vygotsky (1896-1934)* is an old Soviet psychologist and the founder of cultural-historical psychology. His famous work is the idea about "Zone of Proximal Development".

Overall, the key ideas of the constructivist theory involve the understanding of the nature of a learner. The learner is also seen as complex and multidimensional. The background and culture of the learner such as language, logic, and mathematical systems which learner encountered in the past influenced the learning. The interaction with other people make the learner learns across environments. The motivation and responsibility for learning are also major factors for improving learner's ideas (Bransford et al., 1999; Bybee, 2002).

2.3.2 Implications for Instruction

To conform to the constructivism, instructors should act as facilitators. The learning environment should be designed to promote and challenge the learner's thinking. The learning process should be an interactive and social process. The interaction between learner, task and instructor is considered as the important process influencing learner's thinking from the social constructivist. In 1969 the education research, conducted by the National Training Laboratories (Bethel Maine), produced the Learning Pyramid (modified from the Dale' cone in 1954) (figure 2.1), which illustrates that the more active instructions, the more memory retention of children for such subject matters (Lalley & Miller, 2007). The Learning Pyramid provides the average retention rates for different instructional methods. Lecture was found to provide the least retention (5%), and the active methods such as practice by doing and teaching each other were found to provide the most retention (75-90%).

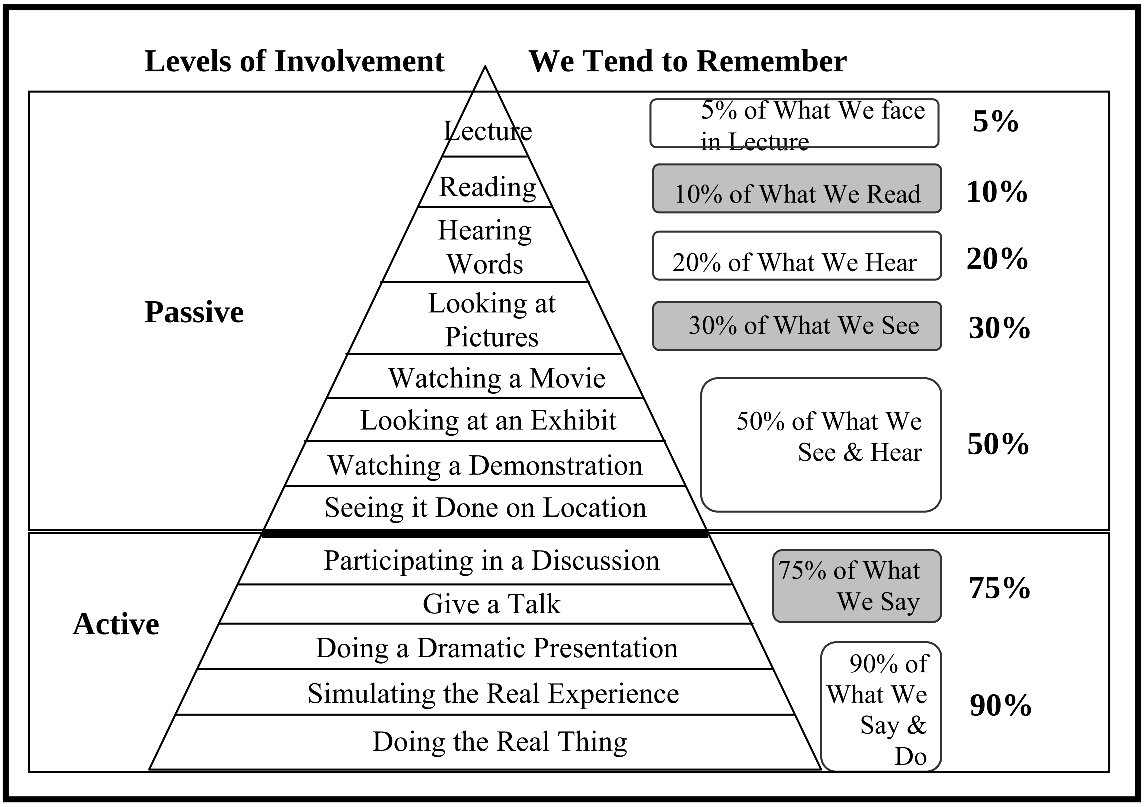


Figure 2.1: The Learning Pyramid (Lalley & Miller, 2007)

Due to the complexity of a learner, instructors should aware that each student does not learn in the same way. This means that if the teacher chooses just one style of teaching, the students will not be maximizing their learning potential. Obviously, a teacher can not reach every student on the same level during one lesson, but implementing a variety of learning styles throughout the course allows all the students have the chance to learn in at least one way that matches their learning style. A given subject matter is matched one proper teaching method (Doğru & Kalender; 2007; Kim, 2005; Liu & Matthews, 2005; Matthews, 2000).

2.3.3 The Inquiry-Based Learning

In the classroom, the constructivist view of learning can point towards a number of different teaching methods. In the most general sense, it usually means encouraging students to use active techniques to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. One of the interesting active learning methods is the inquiry method, which was first proposed by John Dewey in 1909. By the 1950s the rationale for inquiry as an approach to learn science was becoming increasingly evident.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining resources of information to see what is already known; planning investigations; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations as mentioned in the book "Inquiry and the National Science Education Standards: A Guide for Teaching and Learning" by the Center for Science, Mathematics, and Engineering Education (CSMEE) in 2000 (CSMEE, 2000).

Overall, the essential features of classroom inquiry are;

(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 communicate and justify their proposed explanations.

The whole features can be found in "The 5-E Model" of the inquiry instruction methods. It is a learning cycle based on the constructivist approach (Carin et al., 2005). The 5-E model consists of five phases of learning and each phase begins with the letter "E", namely Engagement, Exploration, Explanation, Elaboration, and Evaluation (as shown in table 2.3).

Table 2.3: The 5-E model of the inquiry-based learning method

5 Steps of the 5-E model	Activities
Step 1: Engagement	It serves as an interest approach or a motivator. Teachers build curiosity by using the investigation questions or prior knowledge-based questions.
Step 2: Exploration	Students make discoveries, and share their findings with classmates and the teachers.
Step 3: Explanation	Teachers introduce relevant concepts, principles, or theories based on the descriptions provided by the students. Students and teachers utilize the concepts and the experiences to describe and explain the phenomenon and answer the initial question together.
Step 4: Elaboration	Students create connections between new concepts, principles, theories, and real-world experiences by applying them to a new situation.
Step 5: Evaluation	Assessment of students' knowledge, and the feedback on performance.

2.4 The Assessment Instrument and Method

This session introduces the standard assessment method and instrument used in this study. Our research involves the construction of the earthquake learning module utilized the students' prior knowledge as the primary resource. We explore the students' prior knowledge of earthquakes by using the earthquake conceptual survey, which is based on the well-known assessment instrument in the geosciences field called the Geoscience Concept Inventory (GCI). This will be discussed in the following. Moreover, our learning module will be evaluated its efficiency for helping students to learn the earthquake concepts by using the more recent normalized change, the original normalized gain.

2.4.1 Geoscience Concept Inventory (GCI)

The Geoscience Concept Inventory (GCI) is a multiple choice assessment instrument for using in the earth sciences classroom. The test items cover topics related to general physical geology concepts, as well as underlying fundamental ideas in physics and chemistry, such as gravity and radioactivity. This inventory was built by Libarkin and Andeson, and first published in 2005 (Libarkin & Anderson 2005). The GCI has been developed by using the most rigorous methodologies available, including scale development theory, grounded theory, and item response theory (IRT) (Libarkin & Anderson 2006).

Nowadays, the GCI v.2.1.1 consists of 68 validated multiple-choice questions (Libarkin & Anderson 2006). The GCI could be selected by an instructor to create a customized 15-question GCI subtest for using in the course. The GCI was widely used in researches of the geosciences field (Dahl, et al., 2005; Elkins & Elkins, 2007; Freeman, et al., 2007; Kortz, et al., 2008; McConnell, et al., 2006; Petcovic & Ruhf, 2008).

2.4.2 The Normalized Change

The Normalized change is a method used to assess students' learning gain posted by Marx and Cummings in 2007 (Marx & Cummings, 2007). The normalized change is based on the normalized gain of Richard Hake in 1998. The key idea of this normalized gain method involves the comparison of the different between pre-test and post-test scores to maximum possible gain. This method is quite different from general assessment methods which are usually focused on statistical methods such as t-test, z-test. In general, t-test (or z-test) shows only the significant difference between pre- and post-test scores. But the normalized gain shows the learning gain caused from a given learning method. An average normalized gain (<g>) for a course is the ratio of the actual average gain (<G>) to the maximum possible average gain (<G>max);

$$\langle g \rangle = \%\langle G \rangle / \% \langle G \rangle max$$
$$= (\%\langle post \rangle - \%\langle pre \rangle) /(100 - \%\langle pre \rangle)$$

where <post> and <pre> are the final and initial class averages.

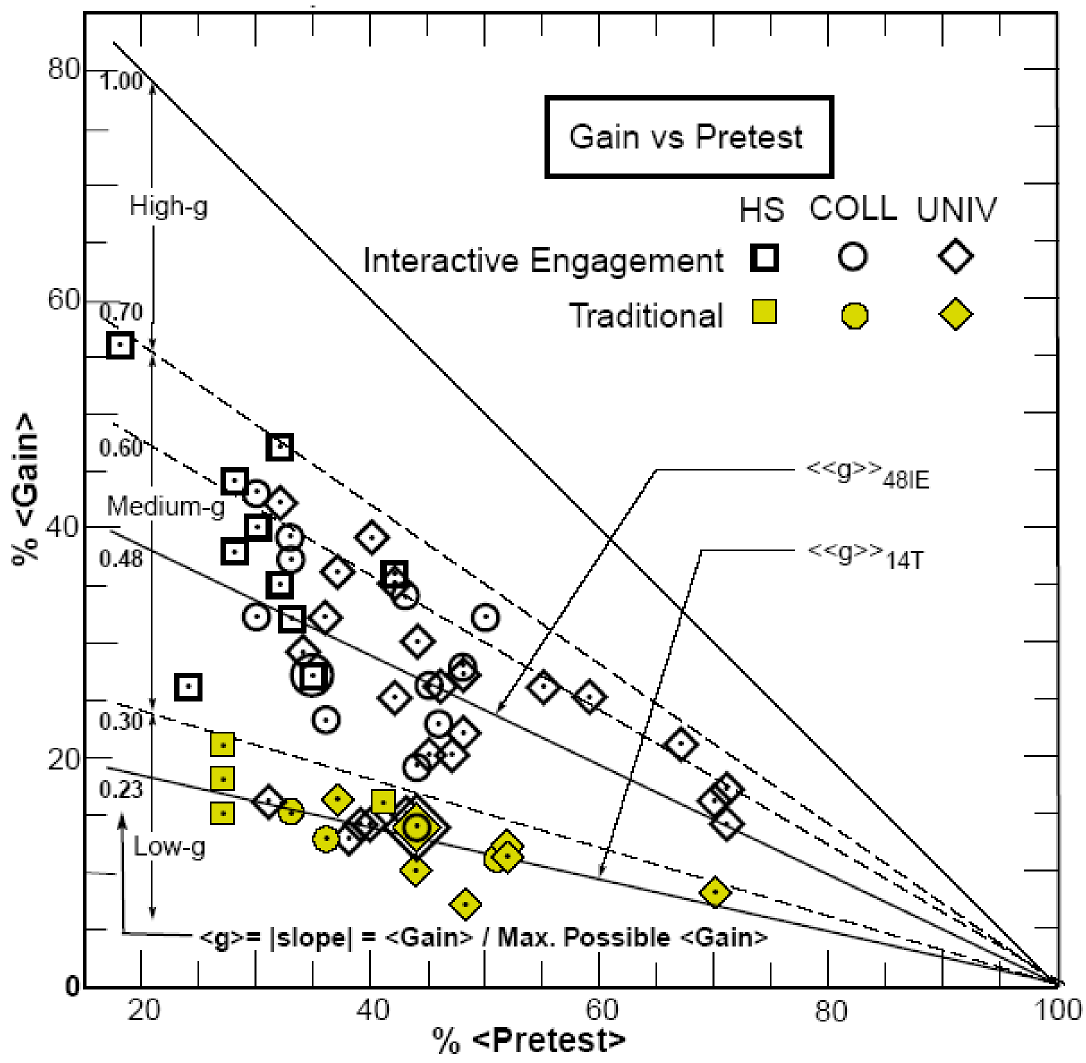


Figure 2.2: %<Gain> versus %<Pre-test> score on the conceptual mechanics diagnostic test called the Force Concept Inventory (Hake, 1998)

Hake (1998) reported the levels of average normalized gains that are the standard values for traditional courses and interactive engagement courses. He surveyed pre-and post-test data in 62 introductory physics courses enrolling a total number of students N = 6,542 by using the Halloun-Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory (FCI). He calculated the average normalized gain for each course and found that traditional courses achieved an average gain 0.23 ± 0.04 (standard deviation). In contrast, interactive engagement courses achieved an average gain 0.48 ± 0.14 (standard deviation) (figure 2.2). Ultimately, based on the study Hake divided the gain values into 3 categories: (1) “High Gain” as

<g> greater than 0.7, (2) “Medium Gain” as <g> between 0.3 and 0.7, and (3) “Low Gain” as <g> lower than 0.3.

In figure 2.2, the graph shows %<Gain> and %<Pre-test> score on the conceptual mechanics diagnostic or called the Force Concept Inventory for 62 courses enrolling a total N = 6,542 students. There were 14 traditional (T) courses (N =2,084) which made little or no use of interactive engagement (IE) methods, and 48 IE courses (N = 4,458) which made considerable use of IE methods. The participants were high school (HS), college (COLL), and university (UNIV) students. Slope lines for the average of 14_T courses and 48_{IE} courses were shown as <<g>>14_T and <<g>>48_{IE}, respectively.

However, Marx and Cummings (2007) showed the limitations of using the normalized gain and revise it to a new procedure called the “**normalized change (*c*)**”. The shortcomings of normalized gain are (1) it has a low test-score bias, (2) the normalized gain equation generates a non-symmetric range of scores which makes interpretation difficult in some cases, and (3) if a student achieves a perfect pre-test score (the maximum scores), then the equation yields $g = -\infty$ for any post-test score. They proposed the normalized change, which its equations are shown in table 2.4.

Table 2.4: The conditions and equations of the normalized change

Conditions	**Equations of the normalized change (c)**
(1) post > pre	c = (post-pre)/(100-pre)
(2) post = pre	c = 0
(3) post = pre = 100 or 0	drop
(4) post < pre	c = (post-pre)/pre

The ways to obtain the normalized change of the class were (1) by calculating each student’s normalized change using above equations and averaging these changes, which called the average of the normalized changes (c_{ave}), and (2) by calculating the average pre-test and post-test of the class and using these two score to calculate the normalized change of the averages (<*c*>). The reasonable investigation for small and medium groups of students was c_{ave}. However, for large numbers of students both $\boldsymbol{c}_{ave}$ and $\langle \boldsymbol{c} \rangle$ revealed the small difference (Marx & Cummings, 2007). Overall, the normalized change can reduce the limitations of the normalize gain. Both assessment methods have been widely used in Physics education research (Bao, 2006; Coletta & Phillips, 2005; Marx & Cummings, 2007).

CHAPTER III
DEVELOPMENT THE EARTHQUAKE LEARNING MODULE

In this chapter, we will discuss about what we have done to develop a new earthquake learning module based on an inquiry approach. That is the major goal of our research, which focuses on the improving of Thai high school students' understanding of earthquakes. We will divide the works into 3 phases namely:

Phase I: identify the basic concepts of earthquakes,

Phase II: survey students' understanding of earthquakes, and

Phase III: design the new earthquake learning module.

The main processes of each phase are summarized in the following figure.

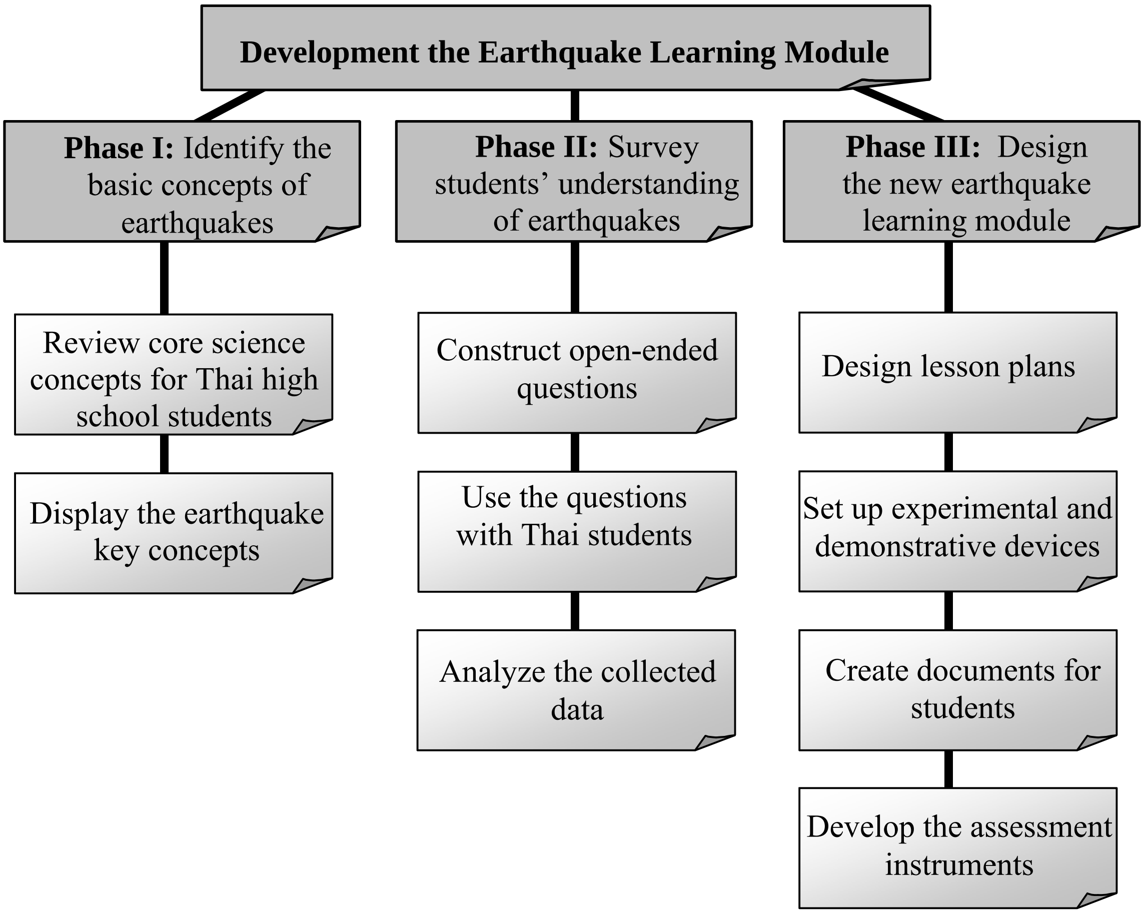


Figure 3.1: The main processes in the development of the earthquake learning module

3.1 Phase I: Identify the Basic Concepts of Earthquakes

In this session, all core science concepts for Thai high school students will be presented, including the basic concepts of earthquakes.

3.1.1 Review Core Science Concepts for Thai high school Students

Based on the act of legislation for the standard curriculum of national education Buddhist Era 2544 (in 2001), there are 8 capital strands of the core science concepts, which all Thai elementary and high school students have to learn. These are;

(1) Living things and living process,

(2) Life and environment,

(3) Matter and its property,

(4) Force and Motion,

(5) Energy,

(6) Earth changing process,

(7) Astronomy and space, and

(8) Nature of science and technology.

3.1.2 Display the Earthquake Key Concepts

An earthquake is a core concept in the 6^{th} strand of them— the earth changing process. In general, the prospective students' achievement, after the teaching and learning of this strand, is that learners should understand the processes at the earth surface, and inside the earth. They should understand the relation among processes, which influence the climate, geography, and structure of the earth. Learners should use the inquiry process for acquiring knowledge and the scientific mind. They should both communicate and apply the body of knowledge in real life situations. To accomplish these goals, the subtopics of the 6^{th} strand of basic science provided for Thai students are illustrated in figure 3.2. The key concepts of earthquakes are shown in figure 3.3 (IPST, 2008).

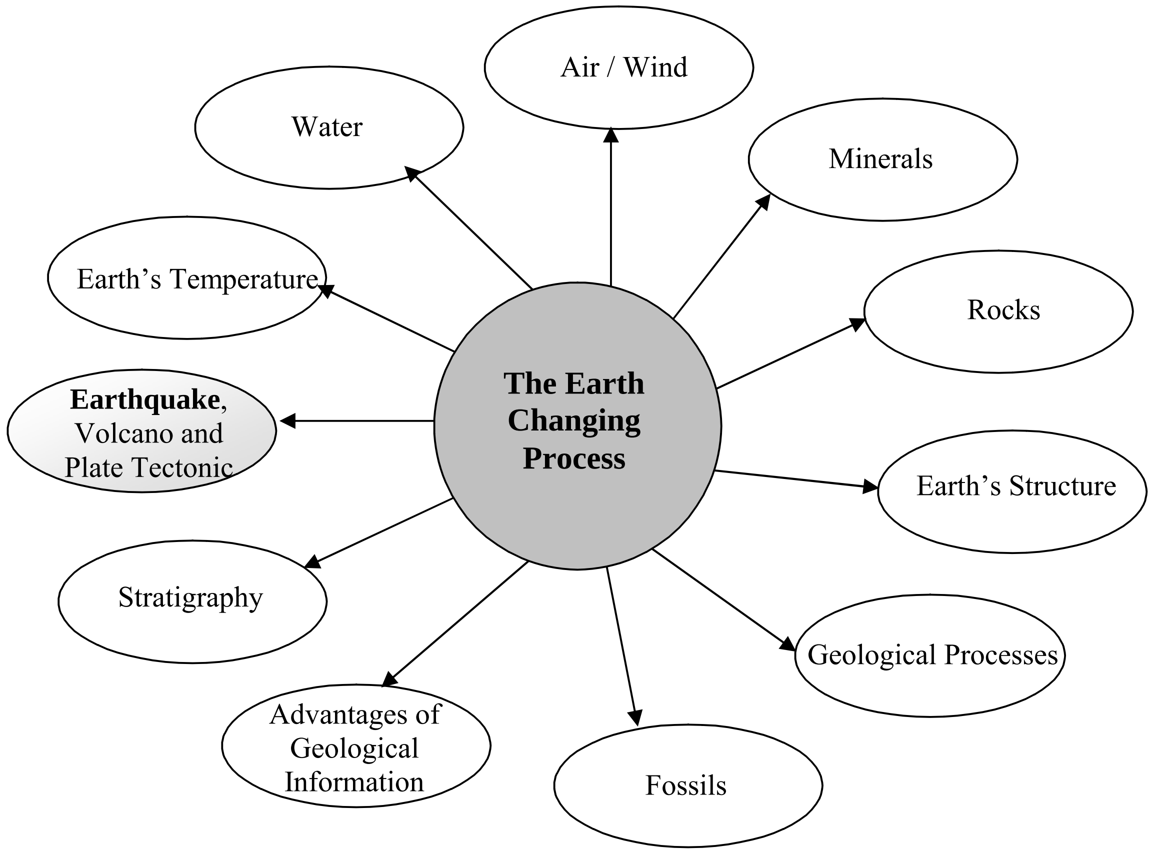


Figure 3.2: Subtopics of the earth changing process (IPST, 2008)

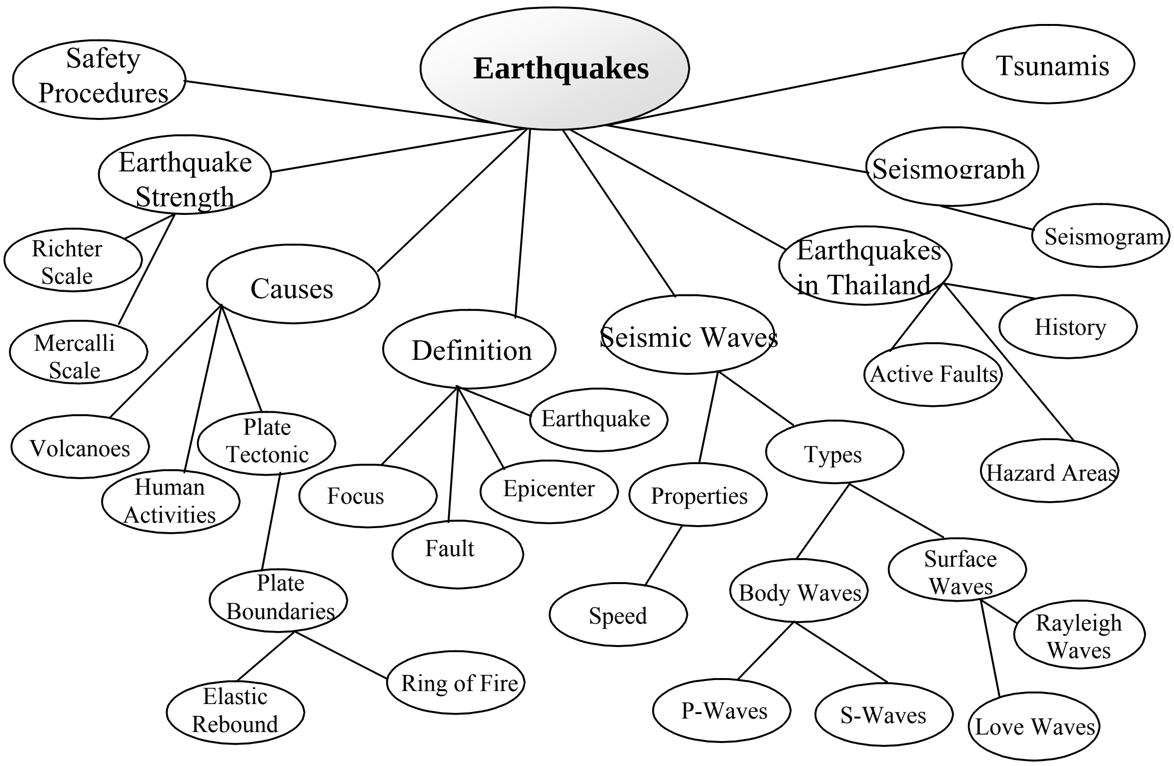


Figure 3.3: Earthquake key concepts for Thai high school students (IPST, 2008)

3.2 Phase II: Survey Students' Understanding of Earthquakes

Since the earthquake concepts have been given to Thai students, in primary and secondary levels, for only 5 years when we started this research, it was a new topic not only for students, but also for teachers. Moreover, from the informal interviews a group of high school students from 13 schools, we found that most students have studied the earthquake topic through the conventional teaching methods, such as traditional lecture, lecture with animation showing and students' presentation. Therefore, exploring what students understand about the earthquake is our preliminary work. We started from construction the open-ended questions, including the validation. These modified questions were utilized with Thai high school students, to survey students understanding of earthquakes. Eventually, we analyzed and classified the collected data to use as a primary resource for construction a new learning module.

3.2.1 Construct Open-ended Questions (called The Earthquake Conceptual Survey)

To examine students understanding of earthquakes, we constructed the conceptual open-ended questions based on previous researches, earth sciences textbooks and educational websites. We started from setting up the objectives of each item, which matched the goals of the standard curriculum of national education, mentioned above.

Each item was measured for content validity by using the Rovinelli and Hambleton (1977) formula called the Index of the Item-Objective Congruence (IOC index) (Rovinelli & Hambleton, 1977). The IOC index is computed using the following equation;

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

where IOC_k is the index of the Item-Objective Congruence of item *k*,

ΣR is the total score of item *k* from the content experts, and

N is the number of content experts.

In this study, five experts, who had at least ten years experience in investigating or teaching earth sciences, were invited to judge the item objective congruence. We constructed a table for each expert to use during the item validation. Each expert assessed the agreement of each item with the stated purpose for the item, and marked: agree (+1 point), in which the item and its purpose correlated, not sure (0 point), or disagree (-1 point), in which the item and its purpose did not correlate. We averaged the scores from all experts for a given item.

Rovinelli and Hambleton (1977) have suggested the guidelines for interpretation that the number of content experts was considered when determining a criterion for item acceptance. In this situation in which five content experts were being used to assess a set of items, a minimal criterion might be the index value that would be attained if a minimum of four of five experts classified an item as a perfect match to an objective (+1 point), while one of five were not able to make a decision (0 point). Clearly, if five experts were used, a value of approximately 0.80 might be used as an accepted value. However, Turner and Carlson (2003) suggested that although the cutoff value was a floating criterion, a generally accepted value might be a minimum of 0.75 (Turner & Carlson, 2003).

Thus our items with Index of Item-Objective Congruence $\geq$ 0.80, equivalent to overall agreement that the item matched its stated objective, were selected for inclusion on the questions. We also modified our questions based upon expert suggestions. An example of the table for validation the Index of Item-Objective Congruence by an expert was shown in appendix A.

These pilot questions were administered to 71 secondary school students who have studied an earthquake topic. To check students' interpretations of items that matched researcher intentions, we analyzed these students' responses and found that all of those matched the item objective (not considered scientific or alternative conceptions). Clearly, the percentage of matching between researcher and student interpretations of an item was the ratio of the number of students, who answered the item that matched researcher intentions, to all participated students, which was multiplied by 100.

Moreover, we calculated the reliability through the Cronbach's Alpha Coefficient (α). It is a measure of internal consistency, which how closely related a set of items are as a group. The Cronbach's Alpha Coefficient (α) is defined as;

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\Sigma_{k=1}^{N} s_k^2}{s_t^2}\right)$$

where N is the number of items, s_k^2 is the variance of item *k*, and s_t^2 is the variance of the whole items (Cortina, 1993; Cronbach, 1951).

The coefficient should be more than 0.70 for proper questions. These questions showed 0.87.

Ultimately, the open-ended questions, which were statistically appropriate for investigation students understanding of earthquakes, consisted of 10 items (1 five-choice question (from the GCI), and 9 open-ended questions). These were called "**The Earthquake Conceptual Survey**". Students took around 15-20 minutes to complete this survey. Two items of the survey used in this research were shown in figure 3.4. Both Thai and English versions of the Earthquake Conceptual Survey were shown in appendix B and C, respectively.

3.2.2 Use the questions with Thai students

We employed the Earthquake Conceptual Survey to explore Thai student comprehension of the earthquake concepts. There were 342 participated high school students (about 57% female) from 9 schools in the southern and central parts of Thailand. These students have learned the earthquake topic before. The instruction took various forms, including traditional lecture, lecture with demonstration via internet animations, cookbook experiments, student presentations, and problem-solving.

Question 3: Do earthquakes occur in rainy areas more than in dry areas? Why?

Question 7: Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot " ●" in the following figure). **Draw the particle motion (at the dot)** when the first earthquake wave (P-wave) arrives. (The direction of wave energy propagation is shown by the arrow below.)

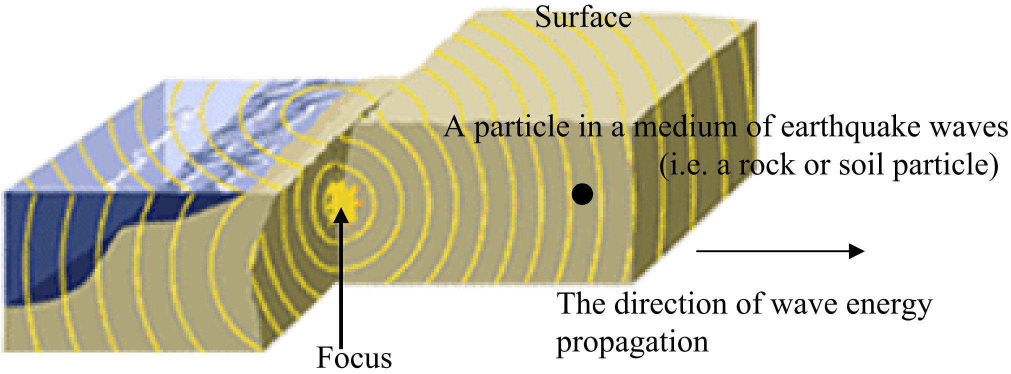


Figure 3.4: An example of two items of the Earthquake Conceptual Survey

3.2.3 Analysis the Collected Data

The collected data via the Earthquake Conceptual Survey were analyzed to clarify what these students knew. We presented the responses by a concept.

(1) Characteristics of an earthquake

Question 1: Which of the following describes what scientists mean when they use the word "an earthquake"? ***Choose all that apply***.

(A) All earthquakes create visible cracks on the Earth's surface.

(B) When an earthquake occurs, the earth shakes at least once every 10 seconds for a period of at least 1 minute.

(C) All earthquakes damage manmade structures.

(D) When an earthquake occurs, energy is released from inside the Earth.

(E) When an earthquake occurs, the gravitational pull of the Earth increases.

Results

This is a GCI question, which comprises 5 choices and students can choose all that apply. The correct answer is choice D, as represented by the circle. We used this question to find the students' understanding of the characteristics of earthquake. In this study we found that only 14% of students correctly understood that when an earthquake occurs, energy was released from inside the earth. But most of them (of about 59%) chose mix correct and incorrect choices, in particular, most students believed that all earthquakes damaged manmade structures. Moreover, twenty-seven percent of them chose the whole incorrect choices (figure 3.5).

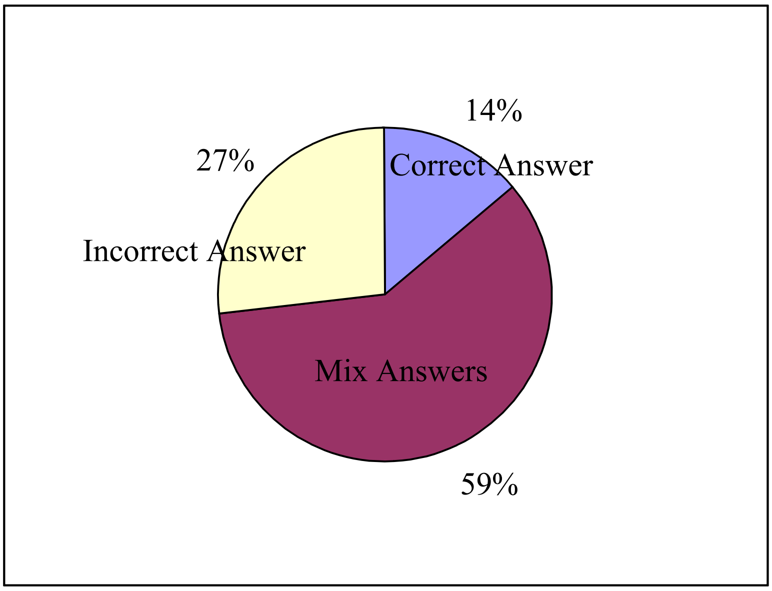


Figure 3.5: Students' responses to characteristics of an earthquake (Q1)

(2) Causes of earthquakes

There are three questions (Q2, Q3, and Q9) used to monitor students' understanding of causes of earthquakes. Q2 also involves the concept of earthquakes in Thailand.

Question 2: Do earthquakes occur in Thailand more than in Japan? Why?

Results

In this question all students said "NO", but they gave obviously different reasons. Their reasons were divided into 5 main keywords (figure 3.6). The study revealed that 36% of students accurately explained the main cause of nature earthquakes, which was the movement of crust, and it occurred at the same location of the volcanic eruption—the eruption could create minor shaking of the earth. Fifteen percent of them thought that the volcano eruption was the main cause of earthquakes in Japan. Seventeen percent of these students thought that earthquake occurrence depended on the topography. Moreover, they believed that earthquakes often occur near islands (14%).

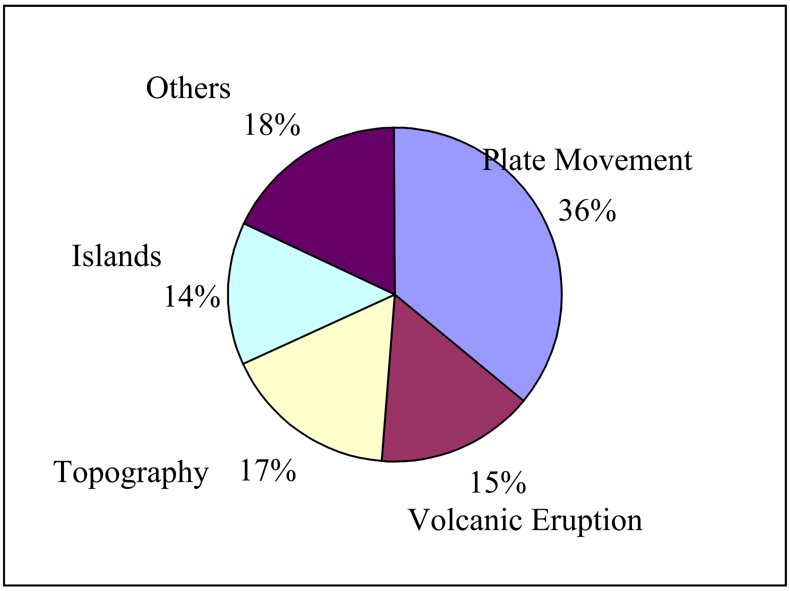


Figure 3.6: Students' responses to causes of earthquakes (Q2)

Question 3: Do earthquakes occur in rainy areas more than in dry areas? Why?

Results

In this question, seventy percent of students said "Yes", and most gave the same reason that wet soil could slab easier than dry soil, which could generate earthquakes easier as well. Merely thirty percent of them accurately explained that the main cause of natural earthquakes was the rupture and sudden movement of crust at plate boundaries.

Question 9: Which factors are the causes of earthquakes? ***(Choose all that apply)***

I Soil Sliding	IV Active Faults
II Islands	V Plate Boundaries
III Volcanic Eruption	VI Equator Zone

Results

There were various responses from these students. In brief, 12%, 51%, 82%, 43%, 89%, and 50% of them chose the soil sliding, island, volcanic eruption, active faults, plate boundaries, and equator zone factors, respectively. Only ten percent of them that chose a group of correct answers for the factors causing the earthquakes, volcanic eruption, active faults, and plate boundaries. Most (44%) revealed mix between islands, volcanic eruption and plate boundaries.

(3) Earthquake Strength

There are two questions (Q5 and Q6) involving the concept of earthquake strength. And Q6 also relates to the concept of seismic waves.

Question 5: What is **the ratio of the ground vibration amplitude** of 8 Richter magnitude scale to that of 6 Richter magnitude scale?

Results

We used this question to probe students' understanding of the medium vibration of seismic waves relative to the Richter magnitude scale. We found that 46% of the students misunderstood that, the ground moved up and down twice as high for the 8 magnitude event as it did during the 6 magnitude. And there was no students realizing that the Richter magnitude scale was the ten based logarithm whose one magnitude corresponds to 10 times. Other answers of this question showed in figure 3.7. This figure shows the percentage of students (y-axis) who responds a given value (x-axis) of Q5.

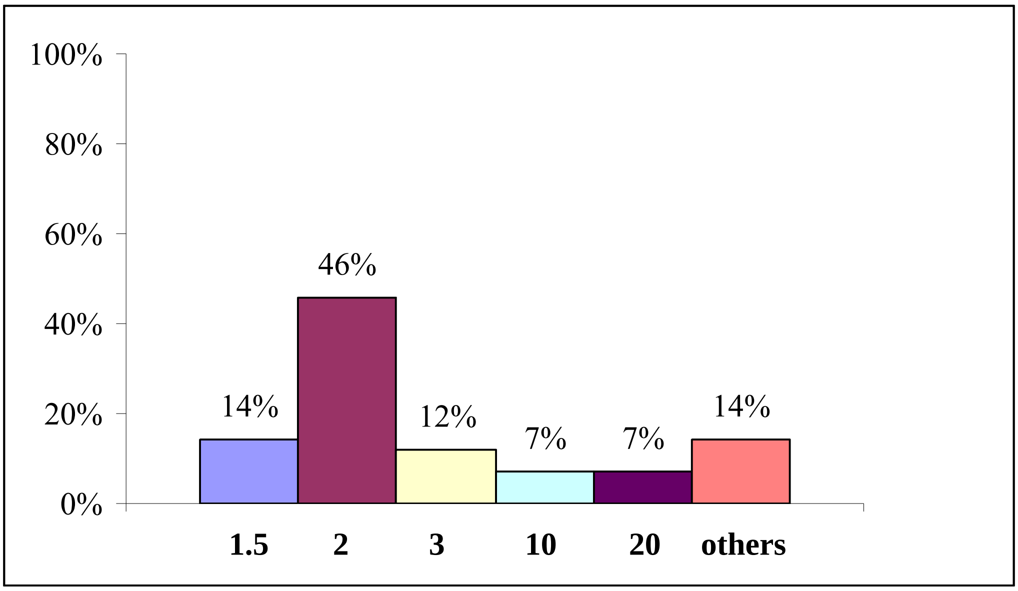
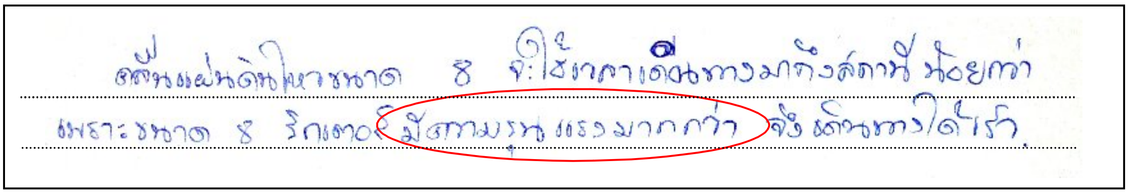


Figure 3.7: Students' responses of earthquake strength (Q5)

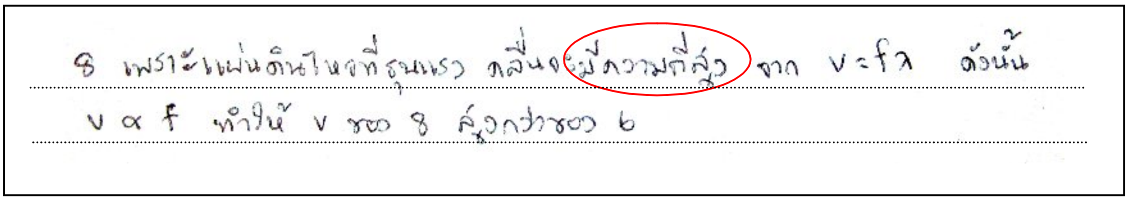
Question 6: If 6 and 8 Richter magnitude earthquakes occur at the same location and the seismic waves of them propagate through homogeneous medium in the same pathway to the same seismic station, which one (6 or 8 Richter scales of earthquakes) takes less time to reach the seismic station? Why?

Results

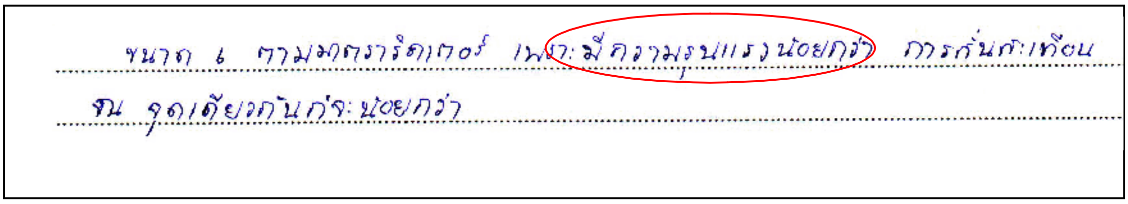
This question related both Richter magnitude scales and seismic wave properties. The result revealed that 87% of students believed that the seismic waves of the 8 Richter scale propagated faster than those of the magnitude 6 in the same homogeneous medium; since the former originated more severity (41% out of the answer), more vibration (33% out of the answer), more energy and more frequency than the later one. Moreover, some students gave the equation, $v = f\lambda$ when v was a seismic wave velocity, f was a frequency of seismic waves and λ was a wavelength of seismic waves, to describe their reasons. The other 13% of students believed that the magnitude 6 moved faster than the magnitude 8 because it had low severity and high frequency. There was no student uncovering the scientific reason that for the same homogeneous medium, the seismic waves moved with the same speed. Students' explanations were shown in figure 3.8.



Translation: The 8 magnitude earthquake takes less time than the other because it is more violent, which it can move faster.



Translation: The 8 magnitude earthquake takes less time than the other because it has high frequency. From the equation v=fλ, so ***v*** α f, then ***v*** of the 8 magnitude earthquake is faster.



Translation: The 6 magnitude earthquake takes less time than the other because it is less violent, which generate less vibration at the same position, as well.

Figure 3.8: Examples of students' explanations for Q6

(4) Seismic Waves

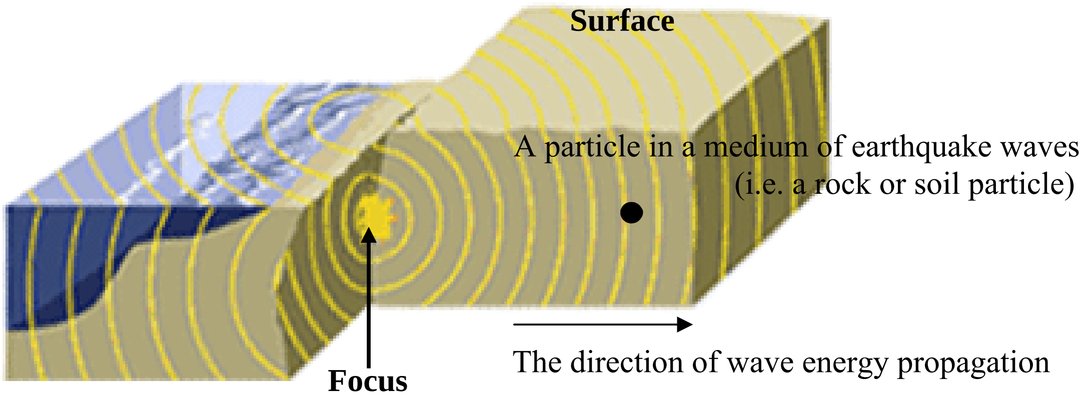
Q4, Q7, and Q8 relate the concept of seismic waves. And Q8 also involves the concept of seismograph.

Question 4: When the first earthquake wave (P-wave) propagates through a soil or rock particle, it will shake the particle like what other kinds of waves?

Results

We found that 40% of these students believed that the first earthquake wave would shake the particle in a medium like that of water waves. Twenty-seven percent, fifteen percent, and seven percent of them believed that it would shake the particle in a medium like that of waves on a string, sound waves (a correct answer), and light, respectively. The others responses were microwaves, radio waves and electromagnetic waves.

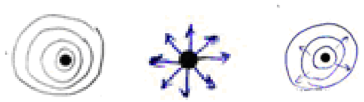
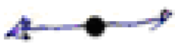
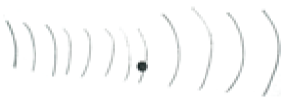
Question 7: Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot " ● " in the following figure). **Draw the particle motion (at the dot)** when the first earthquake wave (P-wave) arrives. (The direction of wave energy propagation is shown by the arrow below)



Results

From students' responses to this question, we found the 5 categories of students' drawings as shown in table 3.1. These 5 categories of the drawings were (1) the particles spread in all directions at P-wave arrival, (2) the particles moved forward like a sine wave motion at P-wave arrival, (3) the scientific idea that particles horizontally moved back and forth at P-wave arrival, (4) the particles vertically moved back and forth at P- wave arrival, and (5) other beliefs such as particles moved forward, or particles went up when P-waves arrived. These suggested student prior knowledge of particle motion at P-wave arrival.

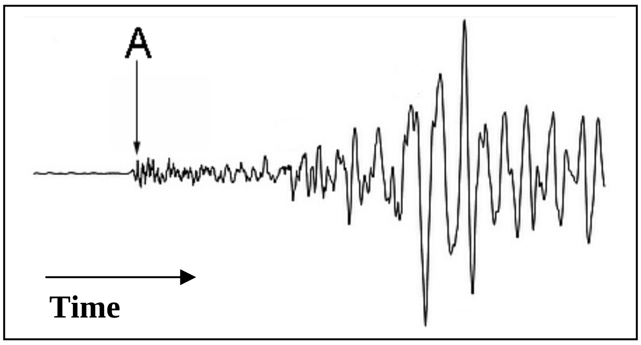
Table 3.1: Five categories of students' drawing from Q7

Group	Students' Drawings	Students' Ideas	% of students
1#	 1(a) 1(b) 1(c)	Students believe that particles spread in all directions at P-wave arrival, and also move along their wave energy. *(alternative concepts)*	**47%**
2#	 2(a) 2(b)	Students believe that particles move forward like a sine wave motion when P- waves arrive, in which these particles move together with their energy. *(alternative concepts)*	**20%**
3		Students' scientific idea is that particles horizontally move back and forth at P-wave arrival. *(the scientific concept)*	**16%**
4		Students believe that particles vertically move back and forth at P-wave arrival. *(alternative concepts)*	**11%**
5	  5(a) 5(b)   5(c) 5(d)	Miscellaneous responses *(alternative concepts)*	**6%**

Note: Here is the direction of wave energy propagation.

Question 8: Consider the position A on the following seismogram. It is the first earthquake wave signal recorded on the seismogram. Assume that the direction of wave energy propagation is from the left to the right hand side of the figure; **describe the particle motion** when the first earthquake wave (P-wave) arrives.

Left

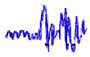
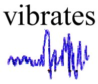


Right

Results

Students' explanations for this question were paraphrased and grouped into five main ideas as shown in table 3.2. This table showed the five groups with English titles, the percentages of students in each explanation group, and an example from each group in both the original Thai and an English translation. Interestingly, students' answers of Q7 and Q8 were very similar (table 3.1 and 3.2), in particular, those categories with symbol #.

Table 3.2: Five categories of students' explanations from Q8

Group	Students' explanations	Examples		% of students
		Thai	English	
1#	Particles move like the signal recorded on the seismogram /move forward like a sine wave motion. *(alternative concepts)*	น่าจะสั่นแบบ 	The particle probably vibrates like this 	52%
2	Particles vibrate back and forth / in the same direction of the wave propagation/ like longitudinal or sound waves. *(the scientific concepts)*	การสั่นของอนุภาคจะมีทิศตามทิศของลูกศร	The particle will vibrate along the direction of the arrow shown in the figure.	18%
3	Particles vertically move back and forth/ like transverse waves/ waves on a string/light. *(alternative concepts)*	ทำให้อนุภาคตัวกลางสั่นตามขวาง ตามลักษณะที่คลื่นเคลื่อนที่ไป	The particle vertically vibrates with the wave movement	11%
4#	Particles spread in all directions/ moves like water waves. *(alternative concepts)*	การสั่นของอนุภาคตัวกลาง เช่น ดิน หิน จะเหมือนกับคลื่นน้ำ	The particle, such as a rock or soil particle, will similarly vibrate with that of water waves.	10%
5	Particles violently vibrate with high frequency. / Particles quake some buildings and collapse them. / Particle vibration generates the Tsunami. / Particles vibration depends on the type of the medium. *(alternative concepts)*	อนุภาคตัวกลางจะสั่นเล็กน้อย และเพิ่มขนาดขึ้นเรื่อยๆ จนหมดความแรงคลื่น	The particle will increasingly vibrate in magnitude until the strange of waves is lost.	9%

(5) Tsunamis

Question 10: Why do tsunamis often occur around the Pacific Ocean? ***(Choose all that apply)***

I	Soil Sliding	IV	Active Faults
II	Islands	V	Plate Boundaries
III	Volcanic Eruption	VI	Equator Zone

Results

The result exposed several student ideas. Most of them (76%) chose the reason of volcanic eruption. Fifty-two percent, forty-two percent, and forty percent of these students chose the reason of plate boundaries (and active faults), equator zone, and islands, respectively. Moreover, most students (40%) thought that tsunamis often occurred around the Pacific Ocean; since there were various islands and volcanic eruptions around this ocean.

In brief, we handled the Earthquake Conceptual Survey to explore Thai students understanding of earthquakes. The results from 342 participated high school students reported some alternative concepts, as above. Some of them, such as outcomes in table 3.1 and 3.2, have been published (Rakkapao et al., 2009). Collectively, what we have found was summarized in the following table.

Table 3.3: The summary of Thai students' alternative concepts of earthquakes

Subtopics of Earthquakes	Students' Alternative Concepts
1. Characteristics of earthquakes	1. All earthquakes create visible cracks on the earth's surface. 2. When an earthquake occurs, the earth shakes at least once every 10 seconds for a period of at least 1 minute. 3. All earthquakes damage manmade structures. 4. When an earthquake occurs, the gravitational pull of the earth increases.
2. Causes of earthquakes	5. Volcanic eruption is the main cause of earthquakes in Japan.

Subtopics of Earthquakes	**Students' Alternative Concepts**
	6. Earthquake occurrence depends on the topography. 7. Earthquakes often happen near the islands. 8. Earthquakes occur in rainy areas more than in dry areas. 9. Soil sliding and locating in the equator zone are the causes of earthquakes.
3. Earthquake strength	10. The ground moves up and down twice (0.33, 3, 10 and 20 times) as high for the 8 magnitude event as it did during the 6 magnitude. 11. The seismic waves of the 8 Richter scale propagate faster than those of the magnitude 6 in the same homogeneous medium; since the former originates more severity (more vibration/more energy/ or more frequency) than the later one. 12. The seismic waves of the 6 Richter scale move faster than the magnitude 8 because it has low severity and high frequency.
4. Seismic waves	13. P-wave will shake the particle in a medium like that of water waves (waves on a string/ light/ microwaves/ radio waves/ or electromagnet waves). 14. A medium's particle will spread in all directions (will move forward like a sine wave motion/ vertically move back and forth/ move forward/ or go up) when P-waves arrive in the horizontal surface.
5. Tsunamis	15. Tsunamis often occur around the Pacific Ocean, since there are various islands and volcanic eruptions around this ocean.

Subtopics of Earthquakes	Students' Alternative Concepts
6. Seismograph	16. Particles move like the signal recorded on the seismogram when the P-wave arrives.

3.3 Phase III: Design the New Earthquake Learning Module

To correct alternative conceptions and promote Thai students' understanding of earthquakes, a new learning module is constructed. This module is designed based on the 5-E model of the inquiry-based learning method. In this session, we will discuss how to build this learning module. We have designed the lesson plans, set up experimental and demonstrative devices, and created documents for students. Lastly, we have developed the assessment instruments for the learning module.

3.3.1 Design Lesson Plans

To construct the new learning module, we reviewed the main goals of earthquake instruction for Thai high school students from the standard curriculum of national education (the 6^{th} strand of basic sciences). Overall, after the finishing of the instruction of this topic, the expected outcomes are;

(1) students are able to do experiment from the artificial situations to discuss the causes and process of earthquakes,

(2) students are able to do experiment from the artificial situations to discuss the seismic waves and their effect,

(3) students are able to explore and discuss the earthquakes of the world,

(4) students are able to search, collect and discuss the earthquake events, its magnitude and intensity scales, and

(5) students are able to search, collect and discuss the earthquake phenomena and their effects in Thailand.

We set up the frame work of this new earthquake learning module by creating the lesson plans, involving the expected students' outcomes. The time for all lesson plans is 300 minutes set by the standard curriculum (IPST, 2008). There are 6 lesson plans (The time for each plan is 50 minutes.), namely;

Lesson Plan 1: The causes of earthquakes,
Lesson Plan 2: Exploring earthquakes in the world and in Thailand,
Lesson Plan 3: Seismic waves,
Lesson Plan 4: The principle of seismographs,
Lesson Plan 5: Locating the epicenter, and
Lesson Plan 6: Magnitude and intensity of earthquakes.

In this study, we developed a lesson plan that consisted of the objectives, teaching tools and teaching processes that based on the 5-E model of the inquiry-based learning method. We introduce the lesson plan 1 as an example. The other plans are shown in appendix D.

Lesson Plan 1: The Causes of Earthquakes

Objective: To demonstrate the mantle convection current and the plate movement by using the demonstration set to challenge students to connect with the causes and process of earthquakes and their effects.

Times: 50 minutes

Teaching Tools:

(1) The convection current demonstration set
(2) Earthquake documentary videos
(3) A4 Papers
(4) Scotch tape
(5) Worksheet 1: The Causes of Earthquakes
(6) Summary document 1: The Causes of Earthquakes
(7) Lecture power point

Teaching Process:

The 5-E model of the inquiry-based learning method	**Times (minutes)**	**Activities**
Step 1: Engagement	10	1) Students watch earthquake videos, and discuss about what happen, why, and did you have an experience in an earthquake.

The 5-E model of the inquiry-based learning method	**Times (minutes)**	**Activities**
		2) Students answer 2 questions in the blank papers and stick the answers on the board in front of the class. **Q1**: What are the causes of earthquakes? **Q2**: Do earthquakes occur in rainy areas more than in dry areas? Why? 3) The instructor groups students' answers of the two questions.
Step 2: Exploration	20	4) The instructor demonstrates the convection current set. 5) Students discuss the demonstration and connect ideas to the cause of plate movement of the earth. 6) Students fill out the worksheet 1 to summarize their own concept about the causes of plate movement and their effects.
Step 3: Explanation	10	7) Students gently push two papers to hit each other on a table. 8) Students discuss the demonstration and connect ideas to causes and process of earthquakes. 9) Students complete the worksheet 1 about the causes and process of earthquakes. 10) The instructor shows the animations of 3 types of the plate movement (convergence, divergence, and transform) and the process of earthquakes.
Step 4: Elaboration	5	11) The instructor describes about the average rate of plate movement in a year. 12) Students and the instructor discuss the volcanic eruption, nuclear explosion, and

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
		meteorite impact, which can generate the earthquakes. 13) Students and the instructor discuss the occurrence of the Himalayan mountain range, the San Andreas fault, and the sea floor spreading.
Step 5: Evaluation	5	14) Back to the students' answers to Q1 and Q2 stuck on the board, students identify and discuss the groups of correct answers for both questions.

In brief, we have designed 6 lesson plans of earthquakes based on the 5-E model of the inquiry-based learning method. We integrated both experiment and interactive demonstration together to help students to learn the earthquake concepts. Moreover, at the end of each class the students will receive the summary document.

3.3.2 Set up experimental and demonstrative devices

This session addresses the development of our experimental and demonstrative devices. Overall, in each lesson plan we use 4-5 teaching tools to promote students learning. All tools for 6 lesson plans are shown in appendix D. Here, we depict an experimental tool (i.e. a simple seismograph) and a demonstration (i.e. a convection current demonstration set).

(1) The simple seismograph

In this study, the main objective of construction the seismograph used in classroom is to help students to understand how the earthquake detector works, in particular, the mechanical process of the signal recording on the seismogram. Therefore, we have developed a simple seismograph from the well known Lehman's seismograph model (Barker, 1987; Mims, 1991; Walker, 1979). It is a mechanical instrument that measures the horizontal shaking directions. This instrument measures the relative motion between the shaking ground and the stable mass, when the quake occurs. The main components of this seismograph are (1) a base frame, which attaches to the floor, (2) an inert mass, which a pen is connected, and (3) a recording part, which comprises a rolling paper and a rotating axis. The first version of our seismograph used in this research exhibited in figure 3.9.

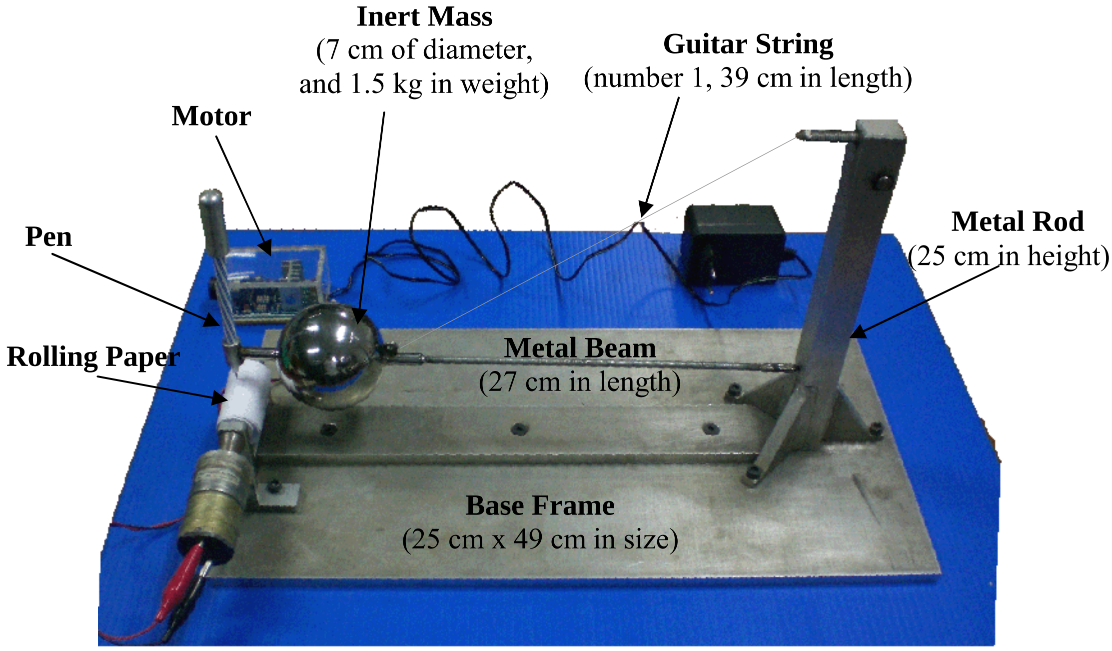


Figure 3.9: The first version of the horizontal seismograph constructed by the researchers

The base frame of this seismograph is 25 cm x 49 cm in size made from the metal. Its metal vertical rod is 25 cm in height. The inert mass is 1.5 kg in weight, and 7 cm of diameter. One end of the mass is glued with the beam (27 cm in length), and is fastened with a guitar string (number 1, and 36 cm in length). The mass is connected to a pen. The rolling paper is driven to rotate by the motor.

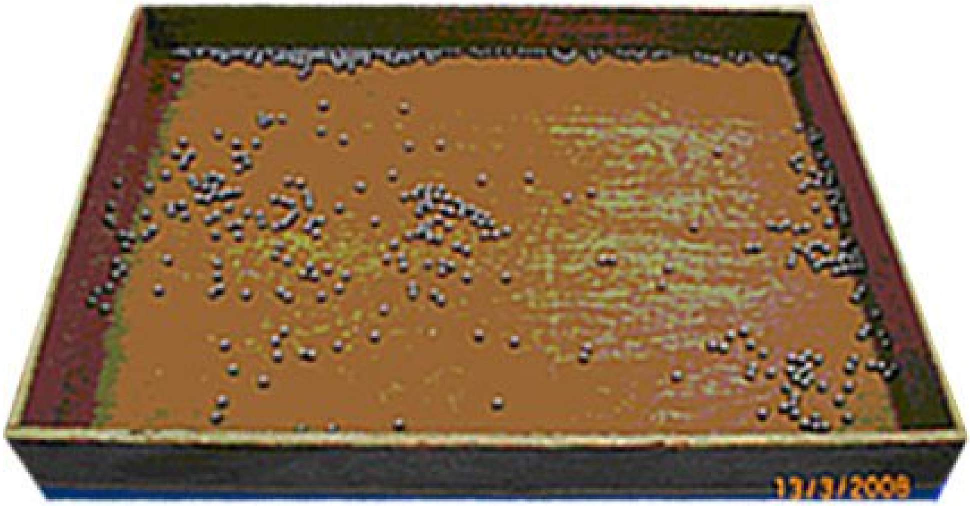


Figure 3.10: A wooden container (42 cm x 57 cm in size) with a large number of bearing balls

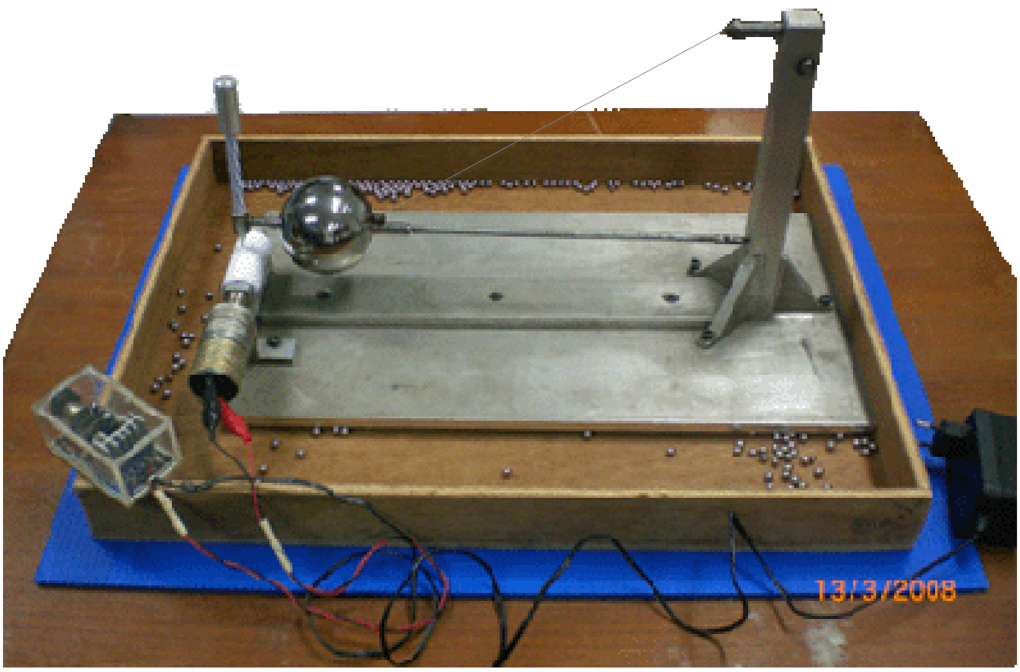


Figure 3.11: The first version of the horizontal seismograph placed on the wooden container comprising a large number of bearing balls

In the experiment, the first version seismograph was placed on the container, comprising a large number of bearing balls. These made the base frame move freely (figure 3.10 and 3.11). To explore how the seismograph works, students shook the base frame. In lesson plan, we assigned students to observe the manmade quake and connected ideas to the principle of the horizontal seismograph. Students discovered that when the base was shaken, the inert mass did not move. So, the pen could draw the signal on the rotating paper. In class, students performed the experiment by using this seismograph, including filled out the worksheet steps by steps. From this experiment, students could learn that the larger the magnitudes of the recorded signal, the larger the magnitudes of earthquakes. Moreover, students could learn about the properties of seismic waves. We have tested the first version seismograph with students. Results from observations and students' satisfactions exposed both advantages and disadvantages of using this seismograph, as shown in the following.

Advantages of the first version seismograph

(1) Students can learn the principle of seismographs.
(2) From the seismograms students can learn about amplitudes, wave lengths, frequencies, and periods.
(3) Students can learn about the P-waves, S-waves and surface waves.

Disadvantages

(1) The inert mass is still moveable, which can lead to the students misunderstanding of the principle of seismographs.
(2) The seismograph is about 5 kg in weight. It inconveniences the instructors/students to transport.

To fix all disadvantages and develop to the more useful seismograph, we remade the former seismograph. The base frame of the second version seismograph was made from the plastic acrylic 34 cm x 39 cm in area. The vertical rod was 33 cm in height, made from aluminum. It was clamped with the base frame with the PVC elephant saddle clips. The inert mass was 1 kg in weight, and 6 cm of diameter. One end of the mass was glued with the metal beam (25 cm in length), and fastened with a guitar string (number 1, and 39 cm in length). The mass was connected to a pen. The rolling paper was rotated by pulling the end of paper. Overall, the second version seismograph was lighter than the former (of about 1.5 kg in weight). The design made the inert mass was unmovable related with the shaking base frame. The figure of the second version seismograph was shown in the following (figure 3.12).

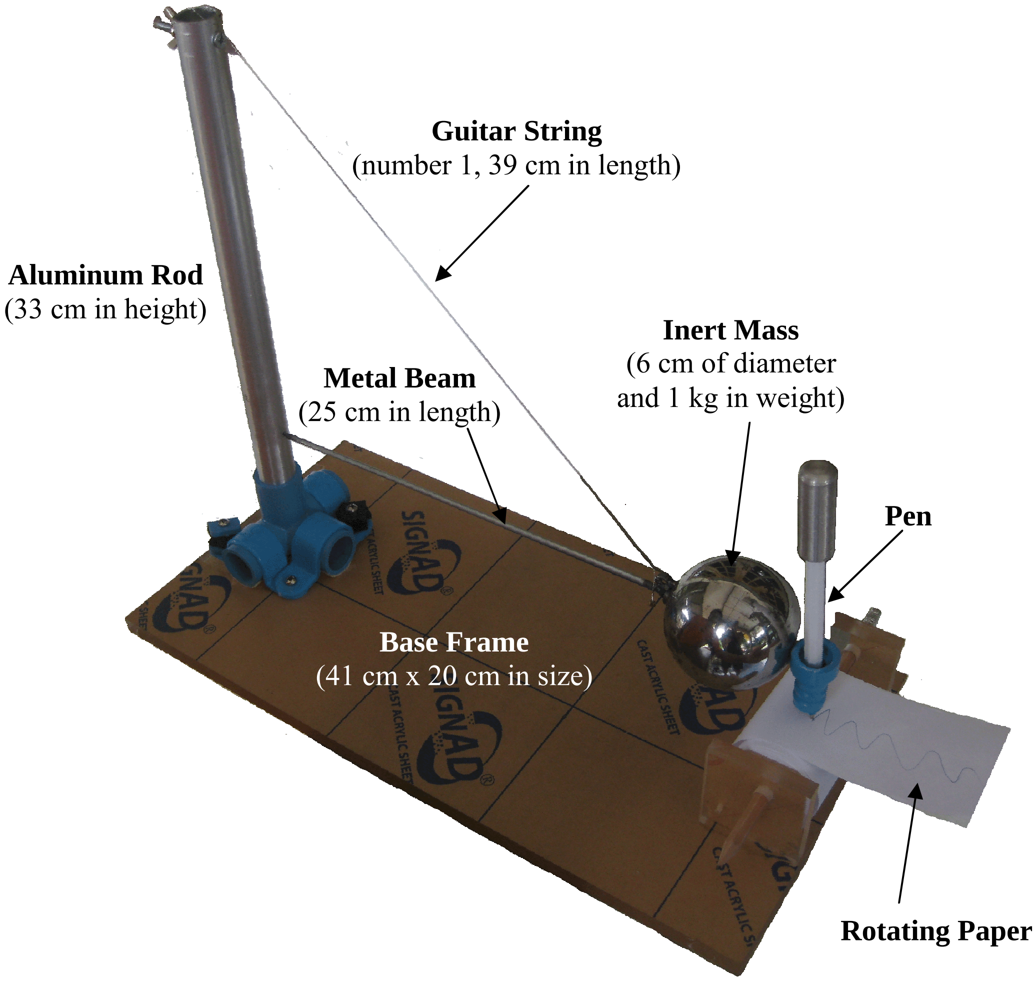


Figure 3.12: The second version of the horizontal seismograph constructed by the researchers

In the experiment, the second version seismograph was placed on the wooden plate (34 cm x 39 cm in size) to shake as artificial earthquakes in the horizontal plane. We made 3 columns on the plate and put 6-8 bearing balls on them to control the motion of the base frame (figure 3.13). Moreover, we stuck a 22 cm long slinky (2 cm of diameter) at one edge of the wooden board, to push for illustration the relation between the medium's motions at P-wave (compressional wave) arrival, and the recording signals on the seismogram (figure 3.14).

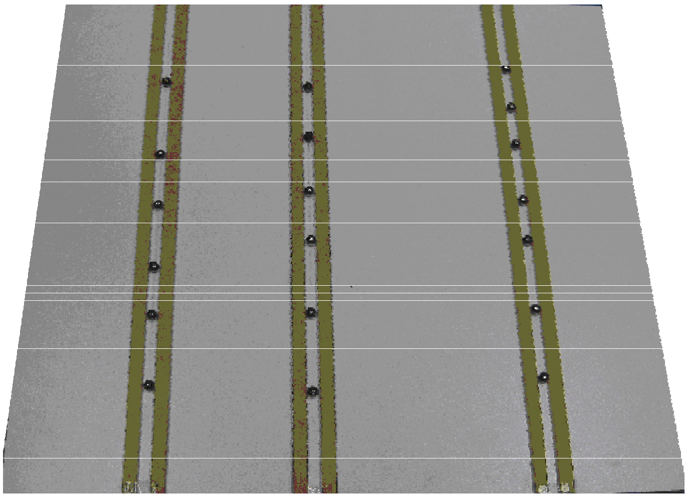


Figure 3.13: A wooden plate (34 cm x 39 cm in size) with 3 columns on the plate (6-8 bearing balls per column)

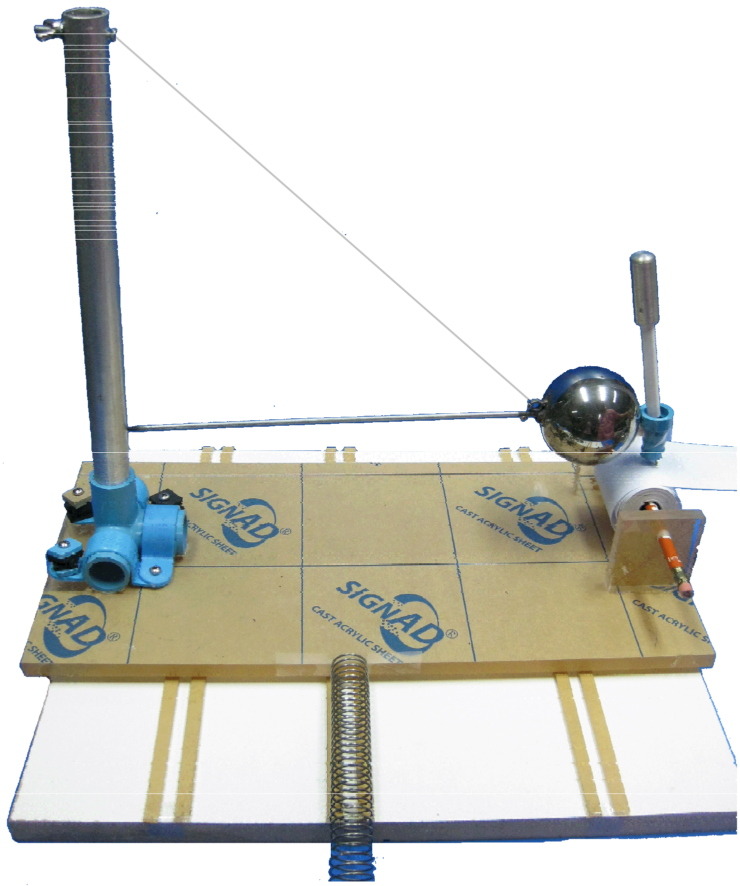


Figure 3.14: The second version of the horizontal seismograph placed on the wooden plate and stuck with the slinky

Advantages of the second version seismograph

(1) Students can perform the experiment to study the mechanical principle of seismographs, including their components and properties.

(2) Students can learn about the anatomy of a wave diagram (amplitude, a wave length, a frequency, a period, a crest, and a trough) by using the seismogram.

(3) Students can learn about the P-waves, S-waves and surface waves.

(4) Students can learn about the relation between earthquake magnitudes and amplitudes of wave diagrams on seismograms.

(5) Students can learn about the relation between the medium's motions at P-wave (compressional wave) arrival, and the recording signals on the seismogram.

For short, our simple horizontal seismograph was developed to advance students comprehension on the topic of earthquake detector principles, in particular, its mechanism. We have built, validated, and modified this instrument for a few years. Ultimately, we obtained the second version of the horizontal seismograph, its worksheet and teaching process as shown in the lesson plan 4 in appendix D, for using in high school classrooms.

(2) The convection current demonstration set

The objectives of construction the instrument were to demonstrate the convection current in the mantle of the earth, and the plate movement to improve students' understanding of earthquake causes. The mantle convection was the heat flow inside the earth, which could move the plates into 3 patterns; convergent, divergent and transform plate movements. The mantle convection was the main cause of the natural earthquakes in the world. This convection current demonstration set was a teaching tool in the lesson plan of the earthquake causes. In the beginning of this research, we have built the demonstration set as shown in figure 3.15. The set consisted of a transparent box (25 cm x 25 cm x 18 cm in volume), a green laser pointer, colloid particles, an alcohol burner, a filter, and pieces of paper.

To demonstrate both the convection current occurrence inside the earth and the plate movement, we set the demonstration as figure 3.15. We filled water in the transparent box around ¾ of its volume, and then mixed the colloid particles into the water. These particles helped students to visibly view the motion of the water. The box was placed on the alcohol burner set. We shone the laser pointer, connecting with the specific filter, on the side wall of the box. The laser beam was adjusted to the vertical plane after passing the filter. In the demonstration, the alcohol burner was heated up. Students discovered that the particles at the bottom of the box went up to the surface, and then fell down to the bottom. This phenomenon took place again and again, as a cycle. Then, we floated 6-8 pieces of paper on the surface of water, which students found that the cycle of water in the box carried the paper together. Students observed both events, completed the worksheet and discussed together. We piloted the first version of the demonstration set with high school students. It showed the positive outcomes of student understanding and satisfaction.

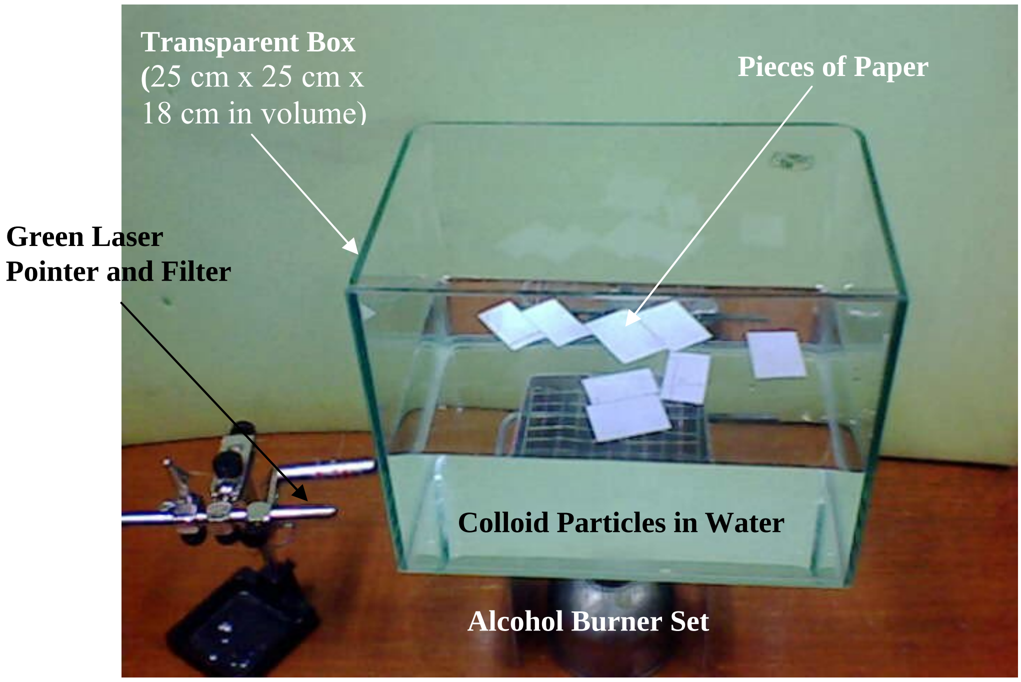


Figure 3.15: Components of the first version of the convection current demonstration set developed by the researchers

However, the colloid particles, the filter and the green laser pointer, used in the demonstration, were not sold in the general markets. To broadly use this demonstration in high school levels, the researchers have rebuilt the demonstration. To accomplish the same objectives, we use vegetable oil and glittering flakes in stead of water and colloid particles, respectively. The second version of the convection current demonstration set was shown in figure 3.16.

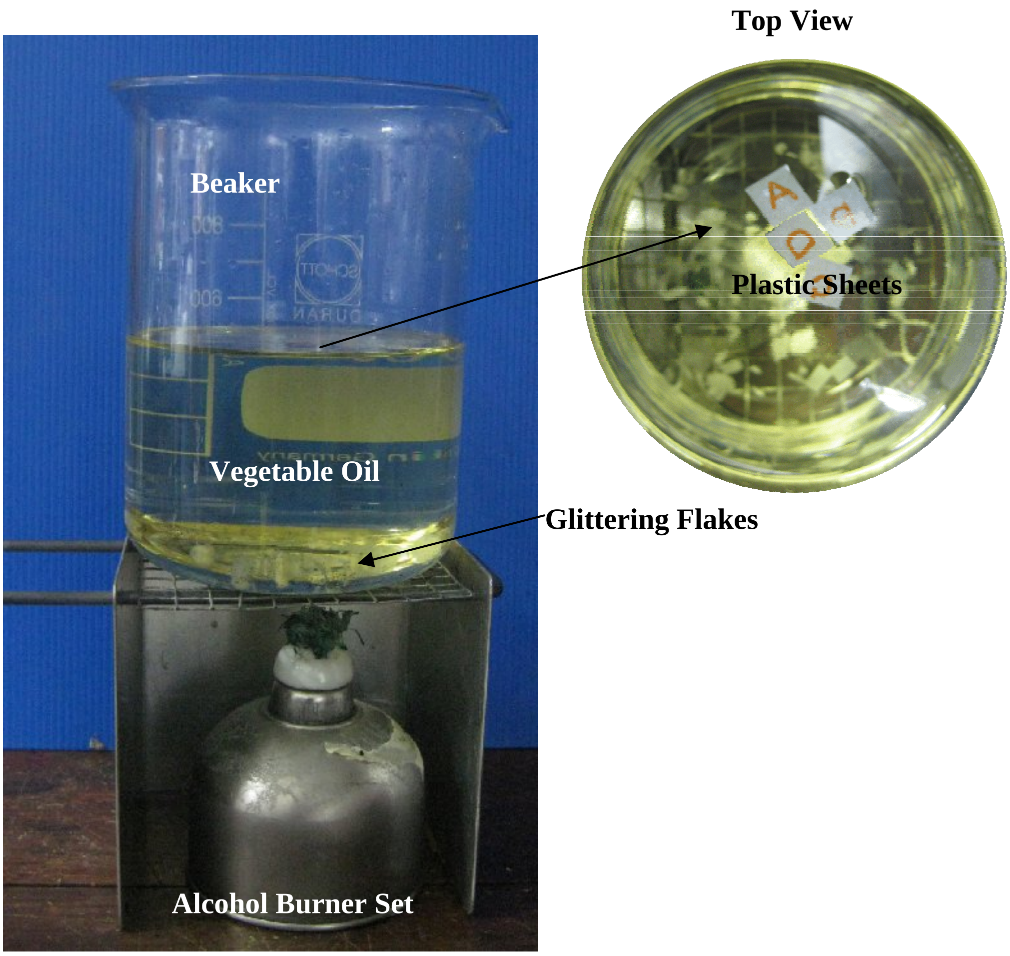


Figure 3.16: Components of the second version of the convection current demonstration set

The second version of the set comprised a beaker, vegetable oil, an alcohol burner set, glittering flakes, and plastic sheets. Since, the movement of glittering flaks in the yellowish vegetable oil was clearly showed by themselves; the laser pointer was not used in this set. In classrooms, we started from setting up the demonstration set (figure 3.16) in the center of the room and asked students to predict the motion of oil's particles represented by the glittering flaks, and the motion of plastic sheets floated on the oil's surface before burning the alcohol burner. Students filled out their prediction in the worksheet. Then the demonstration was illustrated. Students found that during the burning some glittering flaks went up and some went down as a cycle, and the plastic sheets spread in all directions. Students and instructor discussed what happened in the demonstration and connected to the earthquake process. Ultimately, we tested this convection current demonstration set with students and found the positive findings.

For short, we have developed two versions of the convection current demonstration sets for illustration the mantle convection and plate movement for high school students. The second set was composed of low cost materials, which clearly demonstrated the phenomena. The teaching process in classrooms by using this demonstration was shown in the lesson plan 1 in appendix D.

3.3.3 Create documents for students

In this research, we have constructed 2 types of documents for students; worksheets and summary documents. A worksheet was a paper comprising questions and exercises for students in a given lesson plan. A summary document was a text paper that contained the main ideas, outline, and reference resources for each concept. In general, we used a few worksheets and a summary document in each lesson plan. The whole documents for students used in classrooms were exposed in appendix D. Here, we introduced the worksheet for earthquake causes (lesson plan 1) used in classrooms. The worksheet was constructed steps by steps, validated by content experts, and tested with students. The modified version of the earthquake cause worksheet was showed in figure 3.17 both Thai and English versions.

3.3.4 Develop the assessment instruments

To evaluate the learning module, we have developed both conceptual understanding and satisfaction assessment instruments. These were the Earthquake Concept Test (called ECT for short) and the satisfaction questionnaire. The satisfaction questionnaire was showed in appendix E. The ECT was developed from the 10 open-ended questions of the Earthquake Conceptual Survey, as aforementioned. Over 600 students' responses from the survey were analyzed to construct 4 choices of a given question of the ECT. A part of this test has been published (Rakkapao et al., 2009).

Figure 3.17: The worksheet example used in classrooms

Worksheet 1: The Cause of Earthquakes (Thai version)

ชื่อ..นามสกุล.........................

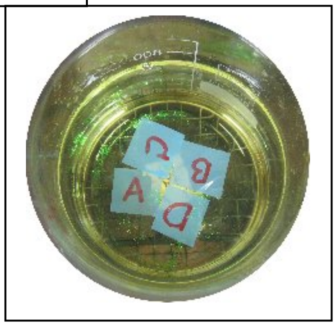
ชั้น.................เลขที่.....................

ใบงานที่ 1 เรื่อง สาเหตุการเกิดแผ่นดินไหว

ทำนาย

1. ให้นักเรียน**<u>ทำนาย</u>** **(a)** ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน (ดูจากกากเพชร) ซึ่งเขียนแทนด้วยจุด ● และ **(b)** การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน หลังจุดตะเกียงแอลกอฮอล์ โดยให้**<u>วาดลูกศรลงในรูปชุดสาธิต</u>**ด้านล่าง

รูปชุดสาธิต



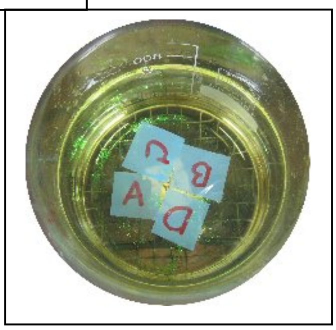
(b) การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน

(a) ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน

คำตอบ

2. ให้นักเรียน**<u>บันทึกสิ่งที่เห็นจากชุดสาธิต</u>** **(a)** ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน (ดูจากกากเพชร) ซึ่งเขียนแทนด้วยจุด ● และ **(b)** การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน หลังจุดตะเกียงแอลกอฮอล์ โดยให้**<u>วาดลูกศรลงในรูปชุดสาธิต</u>**ด้านล่าง

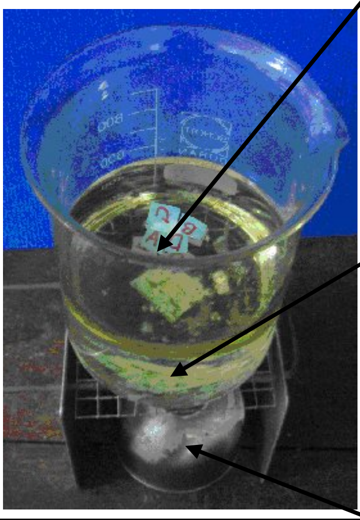
รูปชุดสาธิต



(b) การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน

(a) ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน

3. ให้นักเรียนเลือกโครงสร้างโลก ได้แก่ **แผ่นเปลือกโลก, เนื้อโลก และ แก่นโลก** เติมลงในช่องว่างที่ตรงกับวัสดุของชุดสาธิตที่จำลองสมบัติทางกายภาพของโครงสร้างโลกได้อย่างสอดคล้อง พร้อมบอกเหตุผล



รูปชุดสาธิต

แผ่นพลาสติก	
ทำนาย	**คำตอบ**

น้ำมัน	
ทำนาย	**คำตอบ**

ความร้อนจากตะเกียงแอลกอฮอล์	
ทำนาย	**คำตอบ**

4. จากชุดสาธิต ให้นักเรียน**<u>เขียนอธิบาย</u>**สาเหตุการเคลื่อนที่ของแผ่นเปลือกโลก

Worksheet 1: The Cause of Earthquakes (English version)

Name………………………………

Level……..………..ID……………

Prediction

1. **<u>Predict</u> (a)** the motion of the oil particle (shown by the glittering flakes), which represents in the paper by the dot ● **(b)** the motion of the plastic sheets floated on the oil surface, if the alcohol burner is burned. **<u>Respond by drawing the arrows in the following demonstration set figure.</u>**

The Demonstration Set Figure

(b) The motion of the plastic sheets floated on the oil surface

(a) The motion of the oil particle

Answer

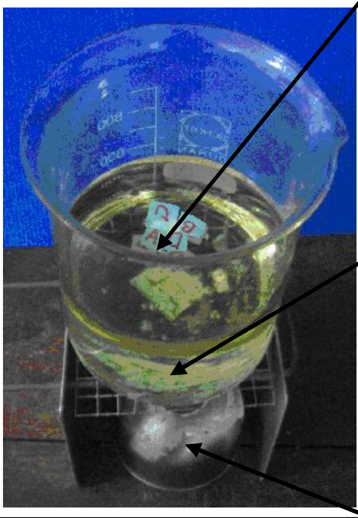
2. **<u>Answers of</u> (a)** the motion of the oil particle (shown by the glittering flakes), which represents in the paper by the dot ● **(b)** the motion of the plastic sheets floated on the oil surface, if the alcohol burner is burned. **<u>Respond by drawing the arrows in the following demonstration set figure.</u>**

The Demonstration Set Figure

(b) The motion of the plastic sheets floated on the oil surface

(a) The motion of the oil particle

3. Fill out the earth's structure terms: **Crust, Mantle, and Core** in the following blanks, which best represent the physical properties of each material of the demonstration set, and give your reasons.



The Demonstration Set Figure

Plastic Sheets	
Prediction	**Answer**

Vegetable Oil	
Prediction	**Answer**

Heat from the Alcohol Burner	
Prediction	**Answer**

4. From the demonstration set, **describe** the cause of plate movement.

Besides, the ECT was validated by experts and students to reach the statistically optimal edition. The statistical tests applied to the ECT were: (1) the content validity test by using the Item-Objective Congruence Index (the IOC index), (2) the reliability test by using the Kuder-Richardson formula 21 method (KR-21 index), and (3) the Item Response Theory of the two parameter-logistic model (IRT-2PL model). We offered a brief statement of each statistics in the following.

(1) The Item-Objective Congruence Index (The IOC index) of the content validity test

As aforementioned, to measure the agreement of each item with the stated objective for the item, we selected to use the Rovinelli and Hambleton (1977) formula called the IOC index (Rovinelli & Hambleton, 1977). We invited the earth science content experts to judge the item objective congruence by using the IOC table. Again, the suitable value of the IOC index is ≥0.75. By five content experts, the final version of our ECT was found to have the IOC index of 0.90.

(2) The KR-21 reliability test

The KR-21 is a method for the reliability calculations. The number shows how consistent participants' responses are among the questions on the test. This calculates an index based on the number of items, the proportion of the responses to an item that are correct, the proportion that are incorrect, and the variance of the two. The formula of KR-21 can be stated as:

$$KR-21=\left(\frac{k}{k-1}\right)\left(1-\frac{\bar{x}\left(k-\bar{x}\right)}{ks^2}\right)$$

where k is number of items on the test, $\bar{x}$ is the mean score of the test, and s^2 is the variance of the test (Variance is the standard deviation squared.).

This index lies in the range of 0-1. The higher values indicate that there is a strong relationship between items on the test. The test is reliable if it has KR-21 greater than 0.70 (Grier, 1975). The last version of the ECT were measured the KR-21 reliability through students' responses (n=268) and revealed 0.75 value.

(3) The IRT (2PL model)

The Item Response Theory (IRT) is a modern mental test theory, also known as the latent trait theory. The idea of IRT was around before year 1960. The pioneers of IRT are such as the psychometrician Frederic M. Lord (1912-2000), the Danish mathematician Georg Rasch (1901-1980), and Austrian sociologist Paul Felix Lazarsfeld (1901-1976). IRT is generally regarded as an improvement over classical test theory, such as the difficulty of items, and the discrimination of items. IRT determines the difficulty and discrimination indices that both depend on the ability of a person. IRT model predicts the likelihood that a person will give a response to an item. Therefore, for the two parameter-logistic model (2PL model) of IRT, the appropriate test should consist of the items, which show that high ability persons can correct both simple and difficult items; in contrast, low ability persons can correct only the simple items. Moreover, medium ability persons should correct around 50% of items in the test. IRT (2PL model) derives the probability of each response as a function of the ability and difficulty and discrimination parameters (Baker, 2001). The equation for the 2PL model of IRT is given below:

$$P(\theta) = \frac{1}{1 + e^{-a(\theta - b)}}$$

where $P(\theta)$ is the probability, θ is an ability level, e is the constance 2.718, a is the discrimination parameter, and b is the difficulty parameter.

In brief, for a reasonable item, the slope of the item characteristic curve from the above equation should look very similar with the S shape. This means that the slope changes as a function of the ability level and reaches a maximum value when the ability level equals the items' difficulty. Students' responses (n=80) from the final version of the ECT were used to analyzed the test analyzed by using the IRT (2PL model). Examples of findings are shown in figure 3.18 and 3.19.

In figure 3.18, Q3 and Q5 are items for evaluation students understanding of earthquake locations. We found that both show very similar S shape curves. It means that both are statistically acceptable to discriminate students into groups of poor and rich knowledge of earthquake locations. However, both questions are quite difficult for these students. The medium ability examinees (In the x-axis, ability is equal 0) can correct both of about 40%.

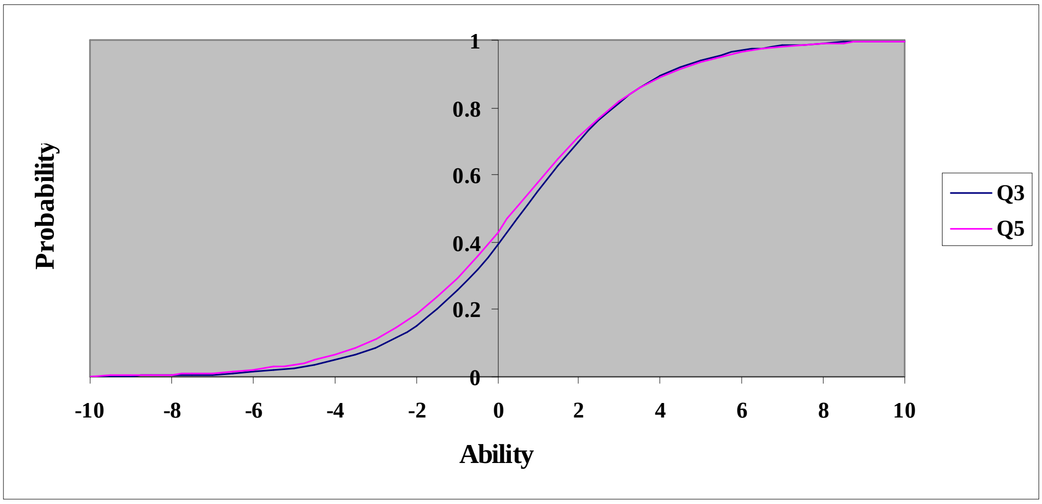


Figure 3.18: Two item characteristic curves (Q3 & Q5), involving the earthquake location concept

In figure 3.19, Q2, Q7 and Q8 are constructed to assess students understanding of P-wave. We found that the characteristic curves of Q2 and Q7 are overlapping each other. Both slightly differ with that of Q8. It means that Q8 can discriminate students into groups more accurate than Q2 and Q7. Whole questions are medium difficult for these students. Around 45% of the medium ability examinees can answer the questions correctly.

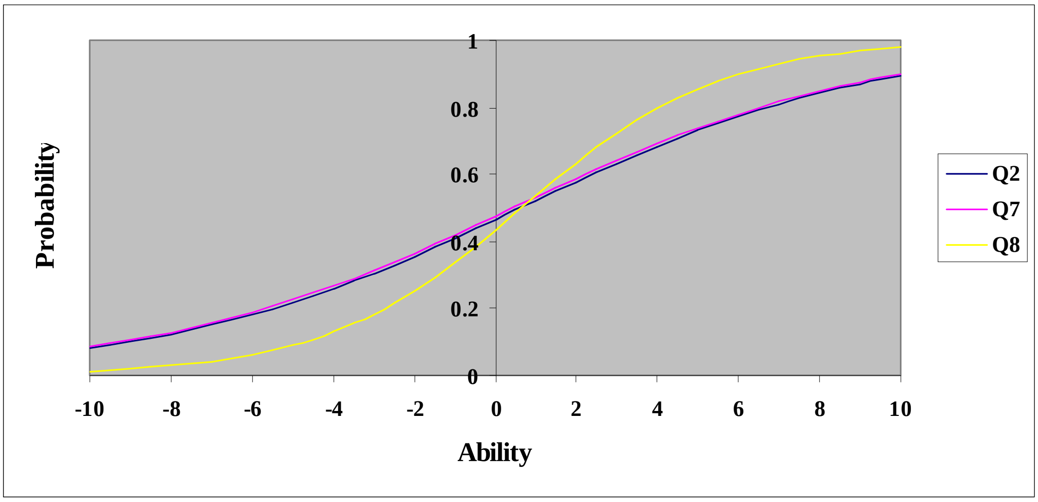
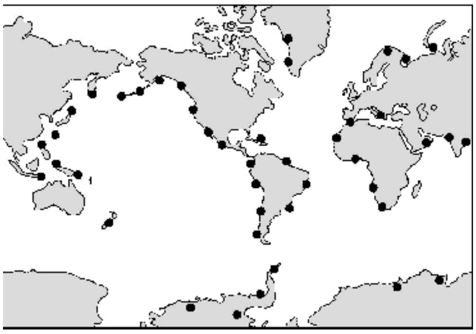


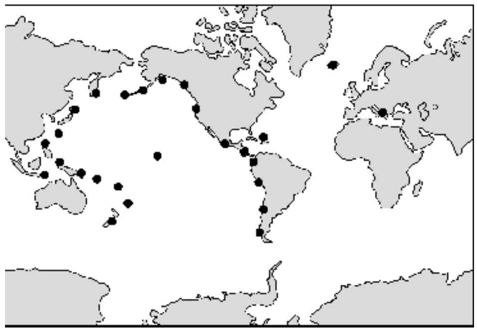
Figure 3.19: Three item characteristic curves (Q2, Q7 & Q8), involving the P-wave concept

Ultimately, we have 10 items of the final edition of the ECT. Both Thai and English versions of the ECT are shown in appendix F and G. Its keys are shown in appendix H. Here, we offer 2 items; Q5 and Q7.

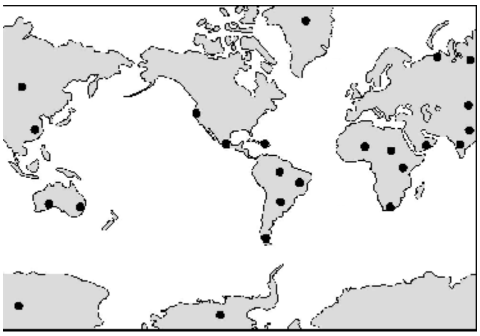
Question 5: The following maps show the position of the earth's continents and oceans. The dots (●) on each map mark the locations of the earthquake region. Which map most closely represents **<u>the area of frequent earthquakes of the world</u>**?



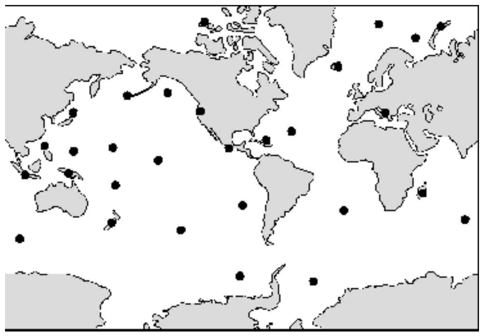
(A) Mostly along the margins of continents and oceans



(B) Mostly along the margins of the Pacific Ocean

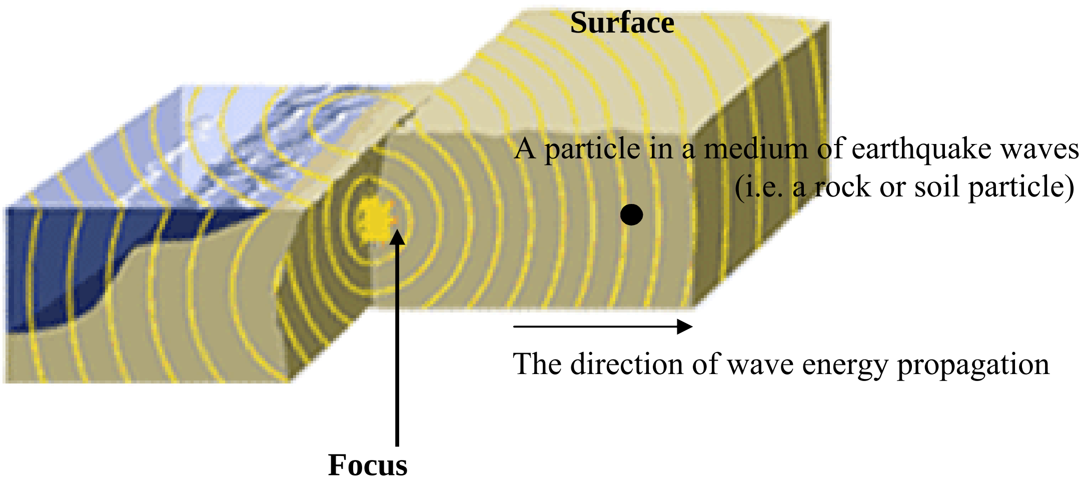


(C) Mostly on continents



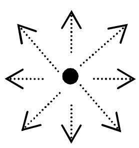
(D) Mostly on islands

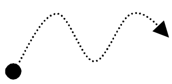
Question 7: Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot " ●" in the following figure). Which response best represents **<u>the particle motion at the P-wave arrival</u>**? (The direction of wave energy propagation is shown by the arrow below)



Assume that ● (a dot) represents a particle of earthquake wave medium (i.e. rock or soil particle)

 (an arrow) represents the direction of the particle motion

A.  The particle spreads in all directions.

B.  The particle moves forward like a sine wave motion.

C.  The particle vertically moves back and forth.

D.  The particle horizontally moves back and forth.

In brief, the ECT was the research based questions for assessment high school students' understanding of earthquakes. It consisted of 10 four-choice questions which were based on the open-ended questions or called the Earthquake Conceptual Survey. Q3 and Q5 were modified items from the GCI. The others were constructed by the researchers. In this research, we used the ECT before and after the teaching process to receive whole students' responses. Students conducted of about 15 minutes to complete this test in the answer sheet. The test could be categorized into concepts as shown in table 3.4.

Table 3.4: The earthquake concept test categorized by concepts

Concepts	Questions
Earthquake locations	3, 5
Particle motion at P-wave arrival	2,7,8
Speed of P-waves	1, 4, 6
Richter magnitude scale	1, 6
The relation among earthquakes, volcanoes, and plate boundaries	3
Earthquake causes	9, 10

3.4 Summary

The major goal of this research is to develop the novel learning module of earthquakes for Thai high school students. We started from the identification of the basic concepts of earthquakes from the standard curriculum of national education Buddhist Era 2544. Then we created the open-ended questions called "The Earthquake Conceptual Survey" to explore students' understanding of such concepts. The survey was administered to 342 Thai students. After the analysis of the collected data, we have designed the learning module, comprising the lesson plans, experimental and demonstration devices and documents for students. All teaching tools were validated to reach the statistically acceptable version, as stated. Eventually, we have developed the assessment instruments, namely the Earthquake Concept Test (called the ECT) and the satisfaction questionnaire, to evaluate the proficiency of the learning module.

CHAPTER IV
RESULTS

Teaching tools in our earthquake learning module were modified to achieve the statistically reliable instrument, as mentioned in the previous chapter. Here, the result chapter addresses what we have found after using the module with Thai high school students. It consists of the context of participated students in this research, the procedures and the results. The results are divided into 3 parts: (1) results from the Earthquake Concept Test (or called the ECT), (2) results from the satisfaction questionnaire, and (3) results from the observation via the videos. Overall, our results have evidently exposed the positive students' learning gain and the satisfaction after the instruction by using our learning module.

4.1 Context

In general, in the high school levels of Thailand, the earthquake education has been provided for students in the 8th and 10th grades (often called Mathayomsuksa 2 and Mathayomsuksa 4). In this study, we focus on the earthquake education for the 10th grades. In 2009, the final version of the earthquake learning module built by the researchers was used with the 10th graders (n = 245, 64% female) for 3 weeks. All participants were Thai students (average age of 16) in 2 middle schools (of about 1300 students in each school) in the southern part of Thailand. In this study, we named the 2 schools as school A and school B. There were 161 participants from school A, and 84 students from school B. These participated students can be divided into 164 students from the science based program (called "S" for short) and 81 students from the non-science based program (called "NS" for short). The science based program students in this study took a physics course that included the topic of mechanical waves in the previous semester. In contrast, non-science based program students did not take any physics course, except for the basic sciences. As stated, all students have learned about earthquakes when they were in the 8^{th} grade. The instruction took various forms, including traditional lecture, lecture with demonstration via internet animations, student presentations, and problem-solving. Before the starting of the earthquake class, all students were taught about the earth's structure by their teachers.

4.2 Procedures

We divided what we have done, for utilization and evaluation our module of earthquakes, into 5 main steps as shown in the following.

Step 1: Three weeks before the starting of the earthquake class, participated students filled out the ECT. This will be called the pre-test.

Step 2: The researcher applied the earthquake learning module to teach the students for 3 weeks, 100 minutes a week (or 2 lesson plans a week). In a given class, observable activities of students or responses were recorded via video. The researcher's instruction was conducted in stead of the conventional instruction by the teacher.

Step 3: When the earthquake classes finished, these students filled out the satisfaction questionnaire of the earthquake learning module.

Step 4: Four weeks after the earthquake class finished, the students filled out the ECT again (called the post-test). Some students were invited to the individual interviews.

Step 5: The researcher analyzed the ECT for evaluation student conceptual understanding by using the normalized change, students' satisfaction, and students' responses from the interviews and the video recording.

4.3 Results

To promote student understanding of earthquakes, we created the new earthquake learning module based on the 5-E model of the inquiry-based learning method. This session exhibited the outcomes of utilization the module with high school students measured by using the ECT, the satisfaction questionnaire, the interview and the video recording.

4.3.1 Results from the Earthquake Concept Test (or called the ECT)

Collected data of the ECT in 2009 were from 215 students administering both pre- and post-tests. These were 145 contributors from school A (67 science based program students (S) and 78 non-science based program students (NS)), and 70 science based program students from school B. Therefore, there were 138 science students (S) and 78 non-science students (NS) in this study. We calculated the pre-test mean score (M_{pre}), post-test mean score (M_{post}), the standard deviations (SD_{pre}, SD_{post}), the t-test (*t-value*, *Sig. (2-tailed)*), and the average of the normalized changes ($\boldsymbol{c}_{\text{ave}}$) and its standard deviation (SD_c) in each group, as shown in table 4.1.

Table 4.1: The ECT scores for 215 students in science (S) and non-science (NS) programs from school A and B with the t-test and the normalized change (Results in 2009)

Statistics	School A (n=145)			School B (n=70)			Total (n=215)		
	S (n=67)	NS (n=78)	total (n=145)	S (n=70)	NS (n=0)	total (n=70)	S (n=137)	NS (n=78)	total (n=215)
M_{pre}	2.33	2.12	2.21	2.49	-	2.49	2.41	2.12	2.30
SD_{pre}	1.00	1.07	1.04	1.21	-	1.21	1.11	1.07	1.10
M_{post}	5.40	3.92	4.61	5.14	-	5.14	5.27	3.92	4.78
SD_{post}	1.37	1.36	1.55	1.63	-	1.63	1.51	1.36	1.59
t-value	16.77	10.87	17.92	14.01	-	14.01	21.55	10.87	22.68
**Sig. (2-tailed)*	< 0.01	< 0.01	< 0.01	< 0.01	-	< 0.01	< 0.01	< 0.01	< 0.01
$\boldsymbol{c}_{\text{ave}}$	0.40	0.23	0.30	0.35	-	0.35	0.37	0.23	0.31
SD_c	0.12	0.10	0.12	0.11		0.11	0.12	0.10	0.12

* We considered at the 99% confidence interval of the difference.

The first column (in the left hand side) of table 4.1 shows the statistical tests calculated from 215 students. The other columns show the results from school A (n=145), school B (n=70) and the total (n=215), which are divided into results from science (S) and non-science (NS) students. Results revealed that post-test mean scores

(M_{post}) were greater than the pre-test mean scores (M_{pre}) of both S and NS, and both schools, proved by the paired t-test at 0.01 significant level. We calculated the students' overall improvement via the average of the normalized changes (c_{ave}). We found the medium learning gain (c_{ave} = 0.31) of these students. Interestingly, we found that the learning gain of science based program students (S) (c_{ave} = 0.37) was greater than the gain of non-science based program students (NS) (c_{ave} = 0.23). These supported that the new instruction, based on the earthquake learning module constructed by the researchers, enhanced student learning to the middle gain region, in particular, science students. It was reported that the gain from the traditional instruction was usually in the low gain region (<g> or c_{ave} was lower than 0.3) (Hake, 1998).

Additionally, in 2008 we used the same ECT to measure students' understanding of such concepts in school A, after the conventional instruction by their teacher. In this year, there were 91 participated students (S; n=56 and NS; n=35), who filled out both pre- and post-tests of the ECT. The findings were showed in table 4.2.

Table 4.2: The ECT scores for 91 students in science (S) and non-science (NS) programs from school A with the t-test and the normalized change (Results in 2008)

Statistics	**School A (n=91)** ***(in 2008)***		
	S (n=56)	NS (n=35)	total (n=91)
M_{pre}	3.41	2.60	3.10
SD_{pre}	1.52	1.14	1.44
M_{post}	4.11	2.74	3.58
SD_{post}	1.50	1.01	1.48
t-value	2.76	0.54	2.58
**Sig. (2-tailed)*	0.01	0.59	0.01
c_{ave}	0.06	-0.01	0.03
SD_c	0.31	0.24	0.29

* We considered at the 99% confidence interval of the difference.

The first column (in the left hand side) of table 4.2 shows the statistical tests namely; pre-test mean score (M_{pre}), post-test mean score (M_{post}), the standard deviations (SD_{pre}, SD_{post}), the t-test (*t-value, Sig. (2-tailed)*), and the average of the normalized changes (c_{ave}) and its standard deviation (SD_c). The others show the results from 91 students in school A, which are divided into S, NS and total. Results of the traditional instruction in year 2008 showed that the post-test mean scores (M_{post}) were not significantly different with the pre-test mean scores (M_{pre}) of both S and NS. These were measured by the paired t-test at 0.01 significant level. The average of the normalized changes (c_{ave}) of these students was lower than 0.3. Clearly, it indicated that the lecture-based traditional method helped students to learn merely in low level gain. Again the learning gain of S and NS in this school were different.

To illustrate how much learning gain, for each concept, of these students after the instruction by using our earthquakes learning module (results in 2009), we calculated the average of the normalized changes (c_{ave}), as shown in table 4.3. Table 4.3 shows 6 concepts of the ECT, including their questions in the first and second columns, respectively. The two last columns show the values of the average of the normalized changes (c_{ave}) for each concept, which are divided into results from science and non-science students. The results from science students manifested that most concepts of the ECT showed c_{ave} greater than 0.30. It indicated that the instruction by using our learning module, particularly for concepts of the earthquake location, the particle motion at P-wave arrival, the relation among earthquakes, volcanoes, and plate boundaries, and the earthquake causes, enhanced students' learning to the middle gain area. But not for the concepts of the speed of P-waves and the Richter magnitude scale; these showed low gain area (c_{ave} was equal 0.15). Overall, findings of non-science students revealed low student learning gain (c_{ave} was lower than 0.30).

Briefly, the results of the ECT revealed that the instruction by using our learning module improved student conceptual understanding of earthquakes into the middle learning gain, examined by the average of the normalized changes. This teaching module was suitable for science students more than non-science. The teaching processes involving the concepts of speed of P-waves and Richter magnitude scale should be revised.

Table 4.3: The average of the normalized changes (c_{ave}) in each concept of the ECT resulted from the instruction by using our earthquake learning module for science (n=137) and non-science (n=78) students (Results in 2009)

Concepts	Questions	Science Students (n=137)	Non-Science Students (n=78)
		c_{ave}	c_{ave}
(1) Earthquake locations	Q3, Q5	0.47	0.25
(2) Particle motion at P-wave arrival	Q2, Q7, Q8	0.42	0.16
(3) Speed of P-waves	Q1, Q4, Q6	0.17	0.13
(4) Richter magnitude scale	Q1, Q6	0.17	0.17
(5) The relation among earthquakes, volcanoes and plate boundaries	Q3	0.51	0.27
(6) Earthquake causes	Q9, Q10	0.46	0.33
All concepts	Q1-Q10	0.37	0.23

4.3.2 Results from the Satisfaction Questionnaire

We evaluated students' satisfaction of this learning module by using the satisfaction questionnaire. The questionnaire was composed of 8 Likert scale items, and 2 open-ended questions. The Likert scales were divided as 1 (strongly disagree), 2 (disagree), 3 (fair), 4 (agree) and 5 (strongly agree). Students were free to select a scale for an item. The satisfaction questionnaire was provided in appendix E. Students took around 5-10 minutes to fill out this document after the finishing of the class. The items of this satisfaction questionnaire were analyzed to find what students thought about our learning module, as shown in figure 4.1.

In figure 4.1, we plotted the 8 items of the satisfaction questionnaire (x-axis) and the percent totals of students, who selected 4 (agree) and 5 (strongly agree) for each item (y-axis). Results (n=236) exposed that more than 80% of these students agreed/ strongly agreed that this learning module help them to learn the topic of earthquakes. In general, most students preferred the summary documents (item 5), and the documentary earthquake videos, involving the everyday life situations (item 8) to the prediction sheets in the demonstration set (item 6). Moreover, from the open-ended questions of the satisfaction questionnaire, some students said that the performing experiment in the simple seismograph activity was very interesting, and they thought the learning by doing was the great method.

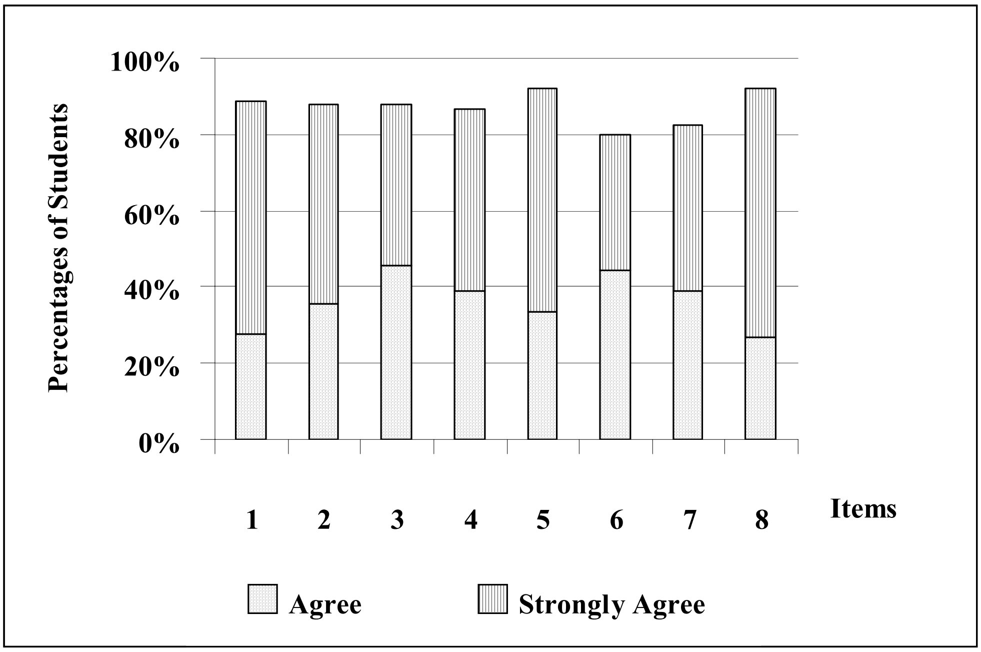


Figure 4.1: The percent totals of students (n=236), who selected agree (4) and strongly agree (5) for the 8 Likert scale items of the satisfaction questionnaire

4.3.3 Results from the Observation via the Video

We recorded the students' responses in classes through the video. These were used as both formative and summative evaluations for the instructor and students. After finishing each class, we watched the class videos. It was used to adjust ourselves and modify the teaching process for the next classes. For example, the instructor added the summary of the ideas at the beginning, and at the end of the classes. Discussing about daily news, events, movies and stories could engage students to think about the science concepts. As shown in the video, when the instructor started to talk about an earthquake event, students stopped their own activities, listened, and discussed each other about the scientific ideas of the event. Students always asked questions about an earthquake movie, which was discussed in classroom, in the free times.

4.4 Summary

In this study, after our earthquake learning module based on the 5-E model of the inquiry method was developed to succeed the statistically reliable teaching tools, it was used with the 10^{th} graders (n=245) in Thailand. After the instruction, we evaluated students learning gain by using the Earthquake Concept Test (ECT), students' satisfaction by using the satisfaction questionnaire, including observing students' behaviors in the classes via the video. Findings revealed that the instruction by using our learning module facilitated students' learning into the middle gain, justified by the normalized change. Clearly, our learning module can be much more effective than lecture-based teaching method in enhancing conceptual understanding of earthquakes, in particular, for science based program students. Most students extremely agreed that this learning module help them to learn about earthquakes. Moreover, the observation via the video indicated that students took pleasure in doing the activities in our earthquake learning module.

CHAPTER V
DISCUSSION

There are three parts described in this chapter. Firstly, we discuss the students' learning by using our earthquake learning module, as the results of the normalized changes, including the comparison with the lecture-based teaching method. Secondly, since the background knowledge influences students' learning, the different learning gains between science and non-science students are discussed. Finally, we address the students' ideas of earthquakes both before and after the instruction by using our learning module, identified by the Earthquake Concept Test (called the ECT).

5.1 Students' Learning from the Earthquake Learning Module

The results in 2008 (table 4.2) and 2009 (table 4.1) obviously illustrated that our new earthquake learning module, based on the 5-E model of an inquiry method, facilitated students learning gain more than that of the lecture-based conventional instruction, as examined by the normalized change. The lecture-based standard instructions mentioned in this study involve the traditional lecture, lecture with passive demonstration via internet animations, student presentations, and problem-solving. These are low interactive processes, which lack the re-organizing ideas of learners. In contrast, our learning module concentrated on the enquiring knowledge by learners, as the key ideas of the active learning methods. The teaching processes in the module were constructed following the alternative concepts of students. Moreover, we focused on the learning by doing, including as a group. Many experimental and demonstration tools were set up for students. Instructor and students always discussed to exchange ideas in various contexts. These are the ways to promote the conceptual change (DiSessa, 1993; Goldberg & Bendall, 1995; Hewson & Hewson, 1983; Posner et al., 1982).

5.2 The Different Learning Gains between Science and Non-science Students: Results from the Learning Module

Background knowledge influenced students' learning. We found that science students, who had more experiences in physics, often got higher scores of the ECT of pre-test and post-test than non-science students, who had fewer experiences in physics (table 4.1 and 4.2). By using the similar teaching process in the module, both groups of students have exposed the different learning gain. Findings from science students showed the middle learning gain, but low gain for non-science students. This revealed that a teaching process might not suitable for all, because of the complexity of learners. Results indicated that our learning module was proper for science students more than non-science students.

Moreover, in the non-science classroom, we found that most students did not understand the basic words, such as "transverse waves", and "longitudinal waves" in the seismic wave class. This involved students learning in the seismic wave concept. Therefore, to increase non-science students' understanding of earthquakes, we suggested that teachers should pay attention to the background knowledge discussion before the beginning of the classes.

To show the percentages of science and non-science students, who chose correct choice of each item of the Earthquake Concept Test (called the ECT) in pre- and post-tests after the researcher' s instruction, we analyzed the 2009 collected data, as shown in figure 5.1 and 5.2.

The ECT consists of 10 questions. It is categorized into 6 concepts namely; (1) earthquake locations (Q3 & Q5), (2) particle motion at P-wave arrival (Q2, Q7 & Q8), (3) speed of P-waves (Q1, Q4 & Q6), (4) Richter magnitude scale (Q1 & Q6), (5) the relation among earthquakes, volcanoes, and plate boundaries (Q3), and (6) earthquake causes (Q9 & Q10). Thus, in figure 5.1 and 5.2, we represented a symbol for a group of questions involving the same concept. For example, circles (a circle with cross (Q1), a white circle (Q4) and a black circle (Q6)) referred to the speed of P-wave concept.

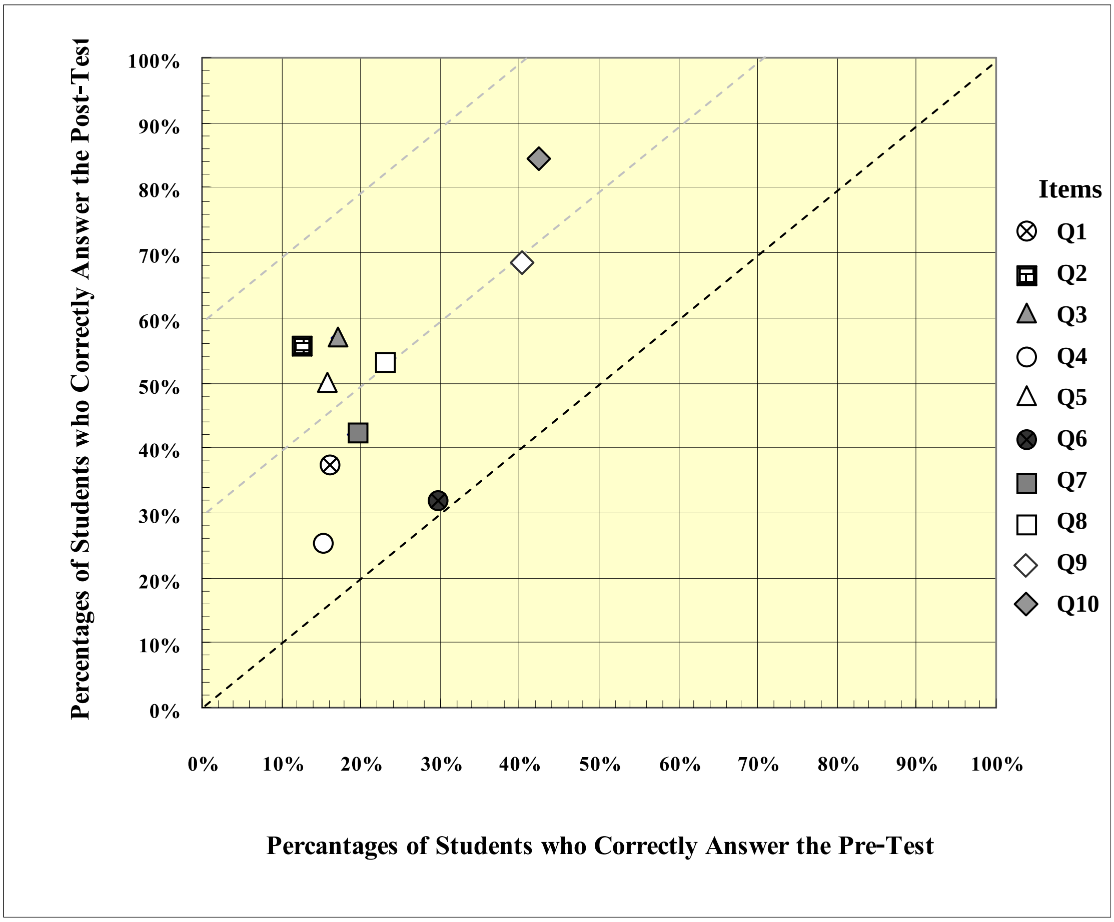


Figure 5.1: The percentages of science based program students (n=137), who correctly answer the post-test (y-axis) versus the pre-test (x-axis) of each item of the ECT

In figure 5.1, the results from the science based program students (n=137) displayed that instruction by using our learning module increased amount of students, who understood the earthquake concepts. Clearly, the amount of students, who correctly answered the post-test, was more than those of the pre-test for all items. Moreover, it exhibited the most different percentages between the amount of students, who correctly answered the pre-and post-tests of the ECT, in the concept of particle motion at P-wave arrival (Q2), earthquake locations (Q3 & Q5), and earthquake causes (Q10).

The outcomes reported that two questions of the earthquake cause concept (Q9 & Q10) uncovered more than 40% of students, who correctly answered the pre-test of the ECT. This indicated that most students in this research (a group of students in the southern part of Thailand) have better prior knowledge of earthquake causes corresponding to the scientific knowledge. The interview results supported that after the 2004 Sumatra-Andaman Earthquake event, which influenced to people in this region, these students were more interested in the earthquake events and would like to understand the phenomena and their effects. Meanwhile, in school, teachers have provided many activities to enhance students' understanding of earthquakes and tsunamis, such as students' debating on the topic of earthquakes, watching documentary videos, poster presentations and inviting speakers to give a talk to these students. Therefore, it is possible that these activities help students to learn, in the earthquake cause concept, in particular.

In figure 5.1 and 5.2, the same structural symbols we plotted involved the same concepts of the ECT. In figure 5.1, we found that the same structural symbols were plotted close to each other. For instance, the black triangle symbol (Q3) was plotted next to the white triangle symbol (Q5). Both Q3 and Q5 indicated the earthquake location concept. This demonstrated the consistency of students' responses in the same concepts. Similarly, Q9 and Q10 of the earthquake cause concept, Q2, Q7 and Q8 of the particle motion at P-wave arrival concept, and Q1 and Q4 of the speed of P-wave concept exhibited the uniform results.

In figure 5.2, the collected data from the non-science based program students (n = 78) showed both similar and different results with those of the former. The amount of students, who correctly answered the post-test were more than those of the pre-test of the ECT, except for Q8. Again, the earthquake cause (Q9 & Q10) was the concept that these students have understood more than the others. Q7 of the particle motion at P-wave arrival was the question, which showed the most different percentages of students between pre- and post-tests. In contrast, Q2 and Q8 of the same concept revealed the least different percentages of students between them. With the exception of the speed of P-wave concept (Q1, Q4 & Q6), we mostly found the disagreement of students' answers in a group of questions involving the same concept.

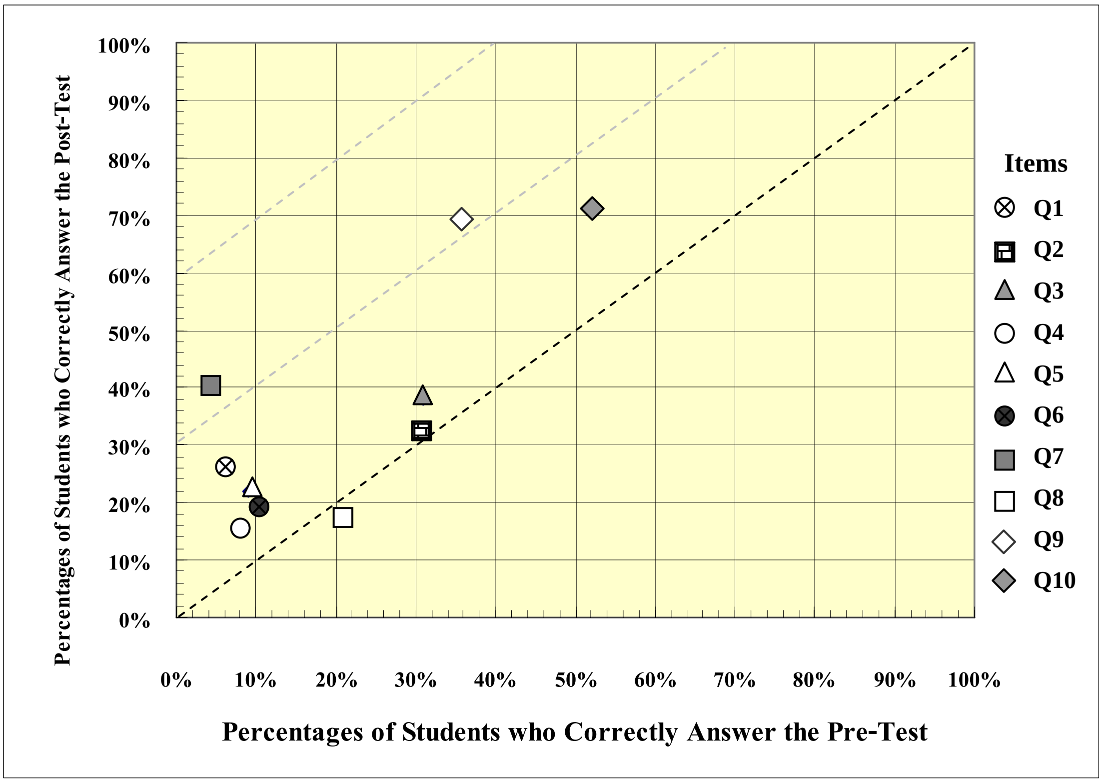


Figure 5.2: The percentages of non-science based program students (n=78), who correctly answer the post-test (y-axis) versus the pre-test (x-axis) of each item of the ECT

We found the incorresponding responses between two groups of students —science and non-science based programs—from the ECT (figure 5.1 and 5.2). Again, this indicated that the two groups of students have differently learned by using our learning module. Science students revealed the lowest understanding in the concepts of speed of P-waves and Richter magnitude scale (Q1, Q4 & Q6), after finishing the new earthquake learning module (figure 5.1). Since, the Richter magnitude scale related to the logarithm concept, which students did not learn before; it is possible that this leads students to the alternative conceptions. At the same time, in our learning module, we had a few times for the speed of P-waves concept. This may not enough for engaging student conceptual change. Overall, science students had greater understanding of earthquakes after finishing the new earthquake learning module.

For non-science students, we often found the inconsistency of students' responses in the same concepts (figure 5.2). Q8 of the particle motion at P-wave arrival concept exposed the lowest understanding, particularly after the finishing of the class. It is the basic concept of the mechanical waves, which non-science students have low background knowledge.

5.3 What Thai Students Think about Earthquakes: Results from the Earthquake Concept Test

To show what science and non-science students have thought both before and after the instructions by using our learning module, we analyzed pre-and post-tests of the ECT in each concept. We compared the percentages of students, who chose each choice, between pre-and post-tests of the ECT, including between science (called "S") and non-science (called "NS") students. Again, the 6 concepts of the ECT are; (1) earthquake locations (Q3 & Q5), (2) particle motion at P-wave arrival (Q2, Q7 & Q8), (3) speed of P-waves (Q1, Q4 & Q6), (4) Richter magnitude scale (Q1 & Q6), (5) the relation among earthquakes, volcanoes, and plate boundaries (Q3), and (6) earthquake causes (Q9 & Q10). These will be demonstrated respectively.

5.3.1 The Earthquake Locations Concept (Q3 & Q5)

Q3. Which of the following responses **best summarizes** the relationship between volcanoes, large earthquakes, and tectonic plates?

(A) Volcanoes and large earthquakes both typically occur in warm climates of tectonic plates

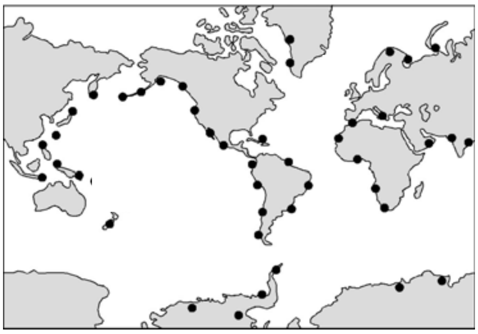
(B) Volcanoes and large earthquakes both typically occur along the edges of tectonic plates

(C) Volcanoes typically occur in the center of tectonic plates and large earthquakes typically occur along the edges of tectonic plates

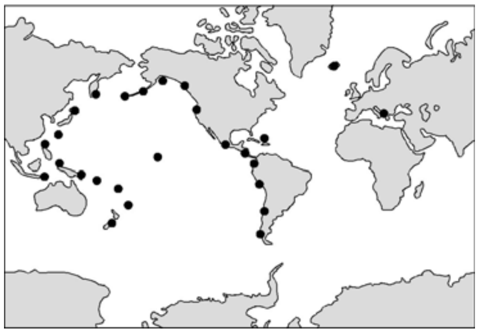
(D) Volcanoes typically occur on islands, earthquakes typically occur on continents, and both occur near tectonic plates

Correct answer for Q3 is choice B.

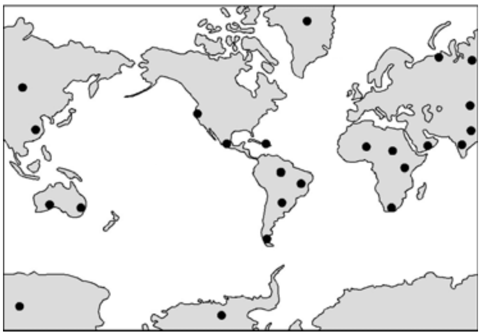
Q5. The following maps show the position of the earth's continents and oceans. The dots (●) on each map mark the locations of the earthquake region. Which map most closely represents **the area of frequent earthquakes of the world**?



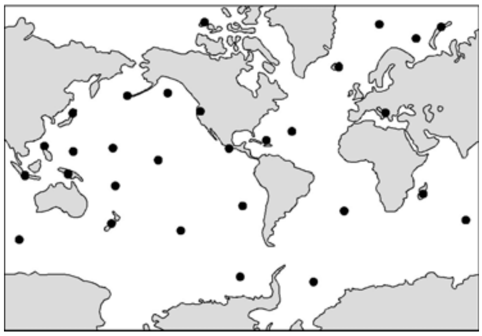
(A) Mostly along the margins of continents and oceans



(B) Mostly along the margins of the Pacific Ocean

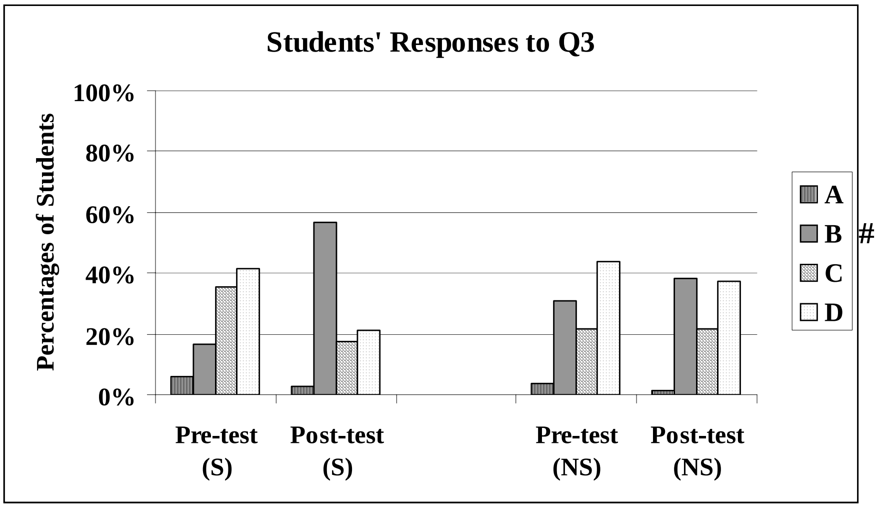


(C) Mostly on continents



(D) Mostly on islands

Correct answer for Q5 is choice B.



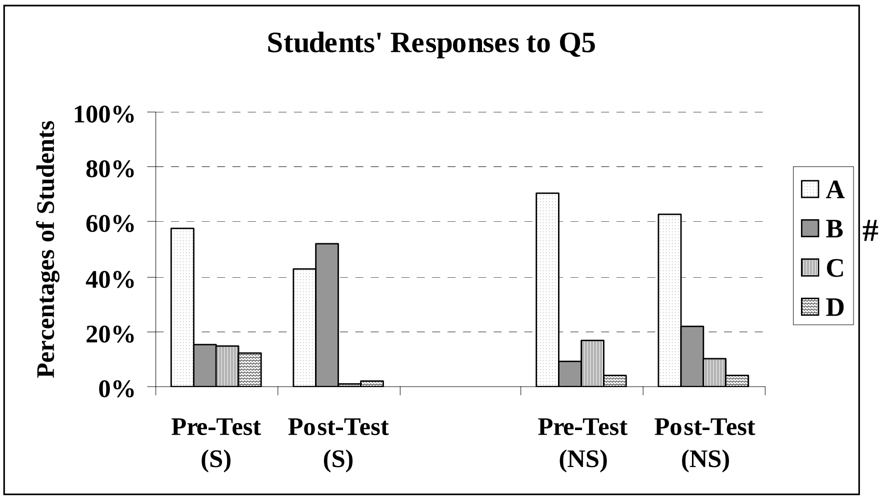


Figure 5.3: The percentages of science (S) and non-science (NS) students, who chose each choice of pre-and post-tests of the ECT in the concept of earthquake locations (Q3 & Q5)

The correct answers of both questions were choice B, as represented by the symbol # and the gray bars in figure 5.3. Before and after the instruction, these students held some alternative concepts. For example, some students believed that volcanoes typically occurred on islands, earthquakes typically occurred on continents, and both occurred near tectonic plates (choice D of Q3). And some believed that volcanoes typically occurred in the center of tectonic plates and large earthquakes typically occurred along the edges of tectonic plates (choice C of Q3). These were similar to results of Q5. In pre-test, most students believed that earthquakes mostly occurred along the margins of continents and oceans (choice A of Q5). Some believed earthquakes occurred on the continent (choice C of Q5). The interview results indicated that these students believed the tectonic plate boundaries were the margins of continents and oceans.

5.3.2 The Particle Motion at P-wave Arrival Concept (Q2, Q7 & Q8)

Q2: When the first earthquake wave (P-wave) propagates through a soil or rock particle, it will shake the particle like what other kinds of waves?

(A) Light

(B) Water waves

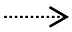
(C) Sound waves

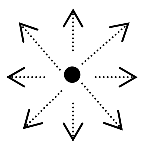
(D) Waves on a string

Correct answer for Q2 is choice C.

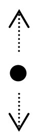
Description: Here are choices (A-D) for Q7 and Q8**.**

Assume that ● (a dot) represents a particle of earthquake wave medium (i.e. rock or soil particle)

 (an arrow) represents the direction of the particle motion

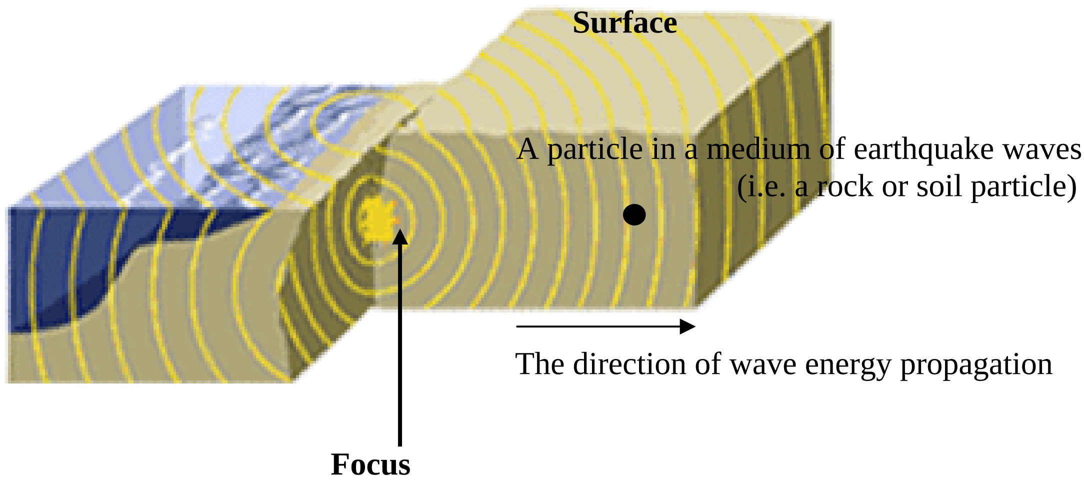
(A)  The particle spreads in all directions.

(B)  The particle moves forward like a sine wave motion.

(C)  The particle vertically moves back and forth.

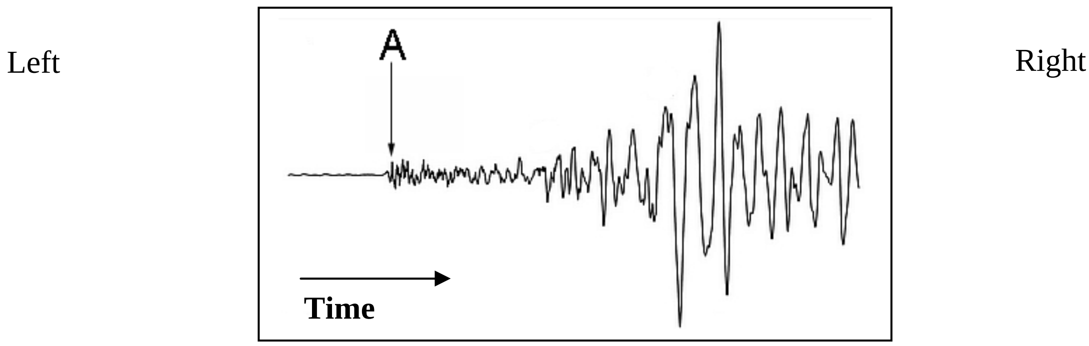
(D)  The particle horizontally moves back and forth.

Q7: Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot " ●" in the following figure). **<u>Which response best represents the particle motion at the first earthquake wave arrival?</u>** (The direction of wave energy propagation is shown by the arrow below)



Correct answer for Q7 is choice D.

Q8: Consider the position A on the following seismogram. It is the first earthquake wave signal recorded on the seismogram. Assume that the direction of wave energy propagation is from the left to the right hand side of the figure; **<u>which response best represents the particle motion when the first earthquake wave arrives?</u>**



Correct answer for Q8 is choice D.

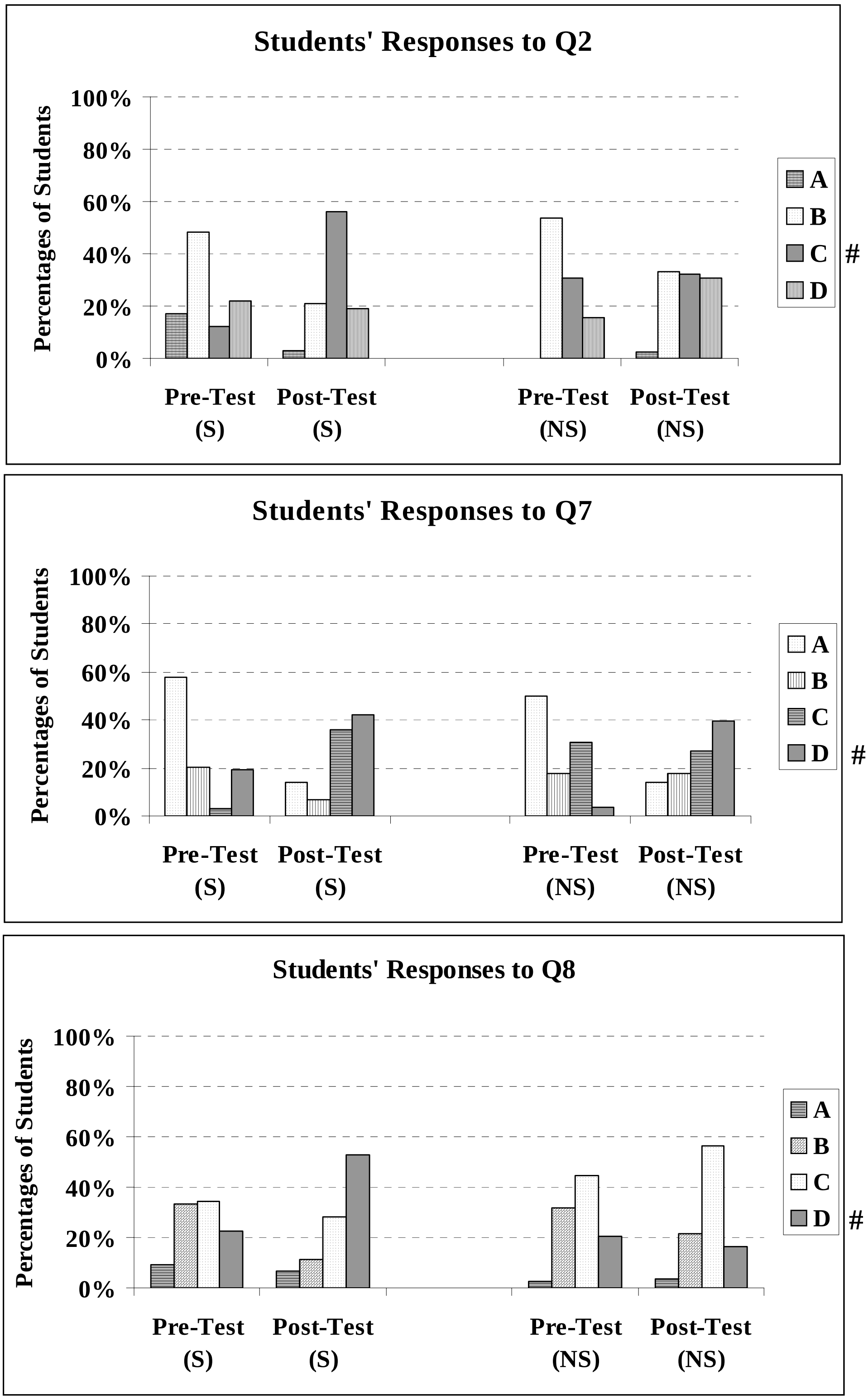


Figure 5.4: The percentages of science (S) and non-science (NS) students, who chose each choice of pre-and post-tests of the ECT in the concept of particle motion at P-wave arrival (Q2, Q7 & Q8)

The correct answers for Q2, Q7 and Q8 were choice C, D, and D, respectively. Q2 revealed that most students believed that P-waves were similar to water waves (choice B) and waves on a string (choice D). Similarly, most students chose choice A for Q7, including choice B and C for Q8. The interview results revealed that students believed that when the soil particles were affected by the P-waves, they spread in all directions, in the same way as a rock thrown into a pool. Therefore, when the P-wave propagated through a soil or rock particle, it would shake the particle as water waves. These suggested the non-scientific idea of the mechanical waves related the medium's particle movement, together with the misunderstanding of the wave front.

For choice A of Q7, some students gave a reason that a series of concentric circles, surrounding a focus of an earthquake, shown in the figure, was similar to the water waves if we throw a rock into a pool, so they thought it was a correct one. This would suggest that most students made a decision in a given question by using their alternative conceptions, which was supported by figures or graphs displayed in the question. The idea about pictures, graphs, or other representations may shape students interpretations of concepts was in line with Elby's (2000) cognitive mechanism called What-You-See-Is-What-You-Get (WYSIWYG). Elby suggested that WYSIWYG was one of several prior knowledge elements contributing to the misinterpretation of a visual representation.

Correspondingly, for Q8, the interview results disclosed that some students believed that the seismogram, shown in the figure, represented the particle motion, which is choice B. A group of students explained that they chose choice C for Q8, because the particle motion (vertically up and down) was inline with the recording on the seismogram as a longitudinal wave. Clearly, the crests and the troughs of the wave diagram shown by the seismogram are in the vertical plane, therefore at the P-wave arrival the particle motion is in the same direction with the plane (choice C of Q8).

We found that these students, particularly non-science students, did not understand the words “longitudinal waves” and “transverse waves”. Back to the classroom, the instructor demonstrated the transverse waves by using a string, and the longitudinal waves by using a slinky. Although these students have experiences in the transverse wave demonstration by a wave on a string, they did not understand that the wave on a string was a type of transverse waves. Clearly, they claimed that a wave on a string was a longitudinal wave, thus it was like the P-wave of Q2 (choice D of Q2). In contrast, some students remembered that the P-wave was a transverse wave, so they chose choice C of Q7. When we prompted these students to think about P-waves as longitudinal waves; most, particularly science students, re-answered the scientific idea (choice D of Q7).

5.3.3 The Speed of P-waves Concept (Q1, Q4 & Q6)

Q1. <u>Situation:</u> the ***5*** Richter earthquake occurs at ChiangRai and its seismic waves propagate to a seismic station at Kanchanaburi for 2 minutes. If the ***5.5*** Richter earthquake occurs at ChiangRai and its seismic waves propagate through the same medium of that of the former to the same seismic station at Kanchanaburi, **<u>does it spend times for 2 minutes? Why?</u>**

(A) Yes, because both have a little different magnitudes.

(B) Yes, because both propagate through the same medium.

(C) No, because the 5 Richter earthquake is a smaller magnitude; it spends less time.

(D) No, because the 5.5 Richter earthquake is more severe one; it moves faster.

Correct answer for Q1 is choice B.

Q4. <u>Situation:</u> A seismic wave is moving through the soil layer. If this seismic wave moves through the rock layer (the equivalent thickness of the soil layer), **<u>does it spend equal times? Why?</u>**

(A) Yes, because it is the same seismic wave.

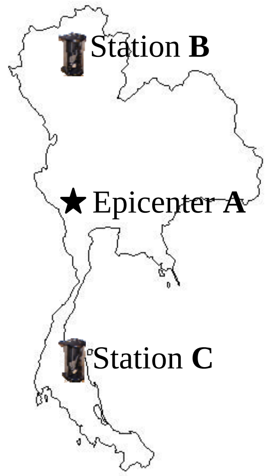
(B) No, because the soil particle vibrates more violent; its wave moves faster.

(C) No, because the rock has more density; its wave moves faster.

(D) Not enough information, it depends on the magnitude of earthquakes.

Correct answer for Q4 is choice C.

Q6. If the 4 Richter earthquake occurs at Kanchanaburi (A), do the two seismic stations (at ChiangRai (B) and SongKhla (C)) detect the P-waves at the same time? Why? (The distances between Kanchanaburi-ChiangRai (A-B), and Kanchanaburi-SongKhla (A-C) are equal.)



(A) Yes, because it is the same 4 Richter earthquake.

(B) Yes, because the distances are equal.

(C) No, because both seismic stations have different directions.

(D) No, because the media of the seismic waves are different.

Correct answer for Q6 is choice D.

For this concept, results in figure 5.5 displayed that most students believed that the speed of P-waves depended on the magnitude of earthquake (Q1, Q4 & Q6). Most thought that the larger the magnitudes were, the faster the P-waves moved (choice D of Q1). For Q4, the interview found that some students thought that the soil particles, which connected to each other looser than that of rock particles, could be vibrated easier than the rock particles. The easier the vibration was, the faster the P-wave moved (choice B of Q4). This was consistent with the previous research, which reported that Thai students believed the speed of a wave on a string depended on the magnitude or frequency of shaking off the string (Tongchai et al., 2009). Clearly, the alternative conceptions about the speed of mechanical waves still were found, after the instruction, in general.

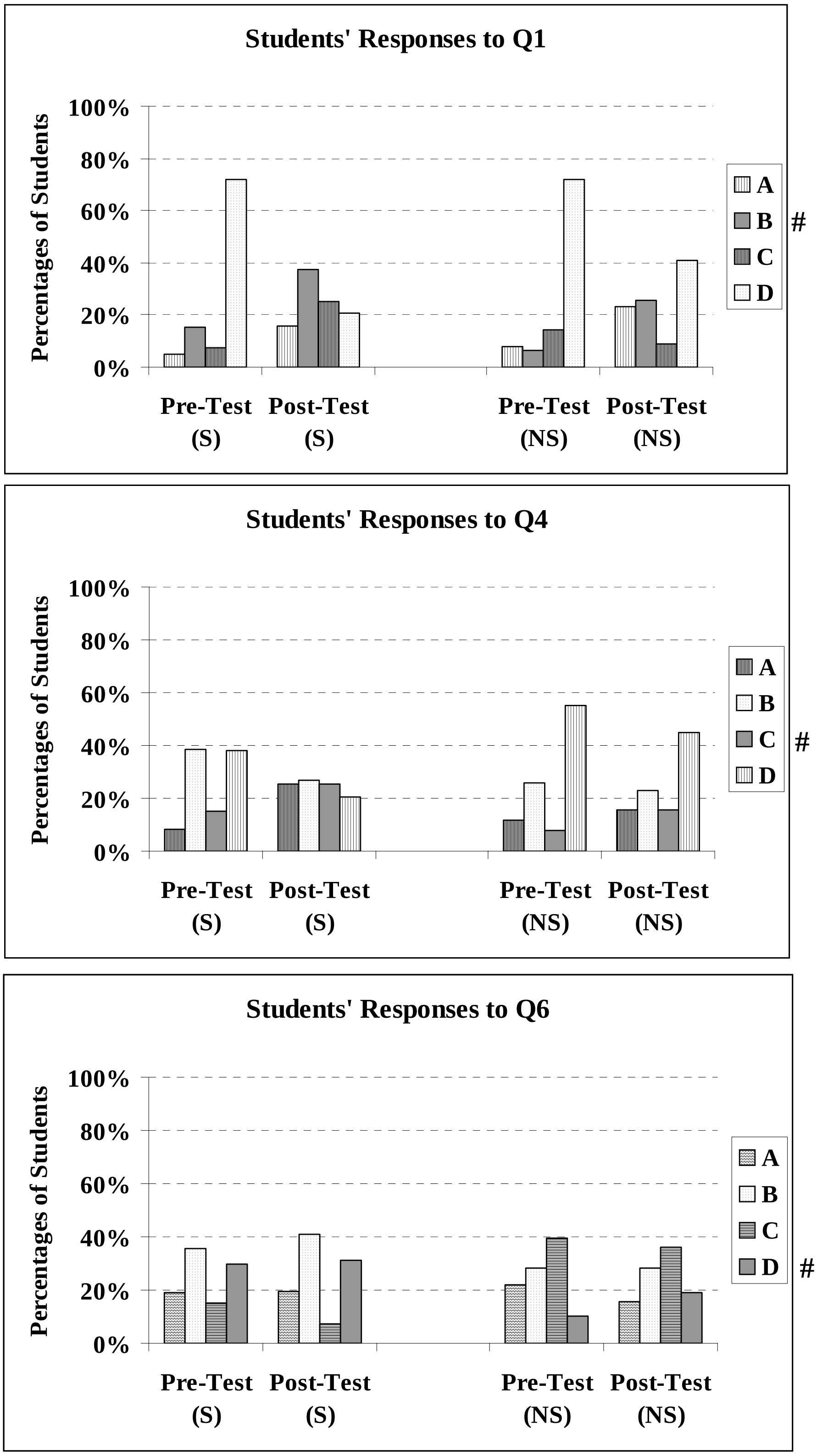


Figure 5.5: The percentages of science (S) and non-science (NS) students, who chose each choice of pre-and post-tests of the ECT in the concept of speed of P-waves (Q1, Q4 & Q6)

5.3.4 The Richter Magnitude Scale Concept (Q1 & Q6)

As aforementioned of Q1 and Q6, most students believed that the magnitude of earthquake affected the speed of P-waves. Moreover, the interview exposed that students have trouble with the logarithm scale. All students have never learned about the logarithm in the mathematics, so that why they thought 5 and 5.5 Richter magnitudes were little different (choice A of Q1).

5.3.5 The Relation among Earthquakes, Volcanoes, and Plate Boundaries Concept (Q3)

After the finishing of the class, around a half of these students understood the relation among them that volcanoes and large earthquakes both typically occurred along the edges of tectonic plates (choice B of Q3). Other alternative concepts (choice C and D) were reduced.

5.3.6 The Earthquake Causes Concept (Q9 & Q10)

Description: Here is information (I-VI) for Q9 and Q10.

I	Soil Sliding	IV	Active Faults
II	Islands	V	Plate Boundaries
III	Volcanic Eruption	VI	Equator Zone

Q9. Which factors are the causes of earthquakes?

(A) I, II and IV

(B) I, V and VI

(C) II, III and V

(D) III, IV and V

Correct answer for Q9 is choice D.

Q10. Why do tsunamis often occur along the margins of the Pacific Ocean?

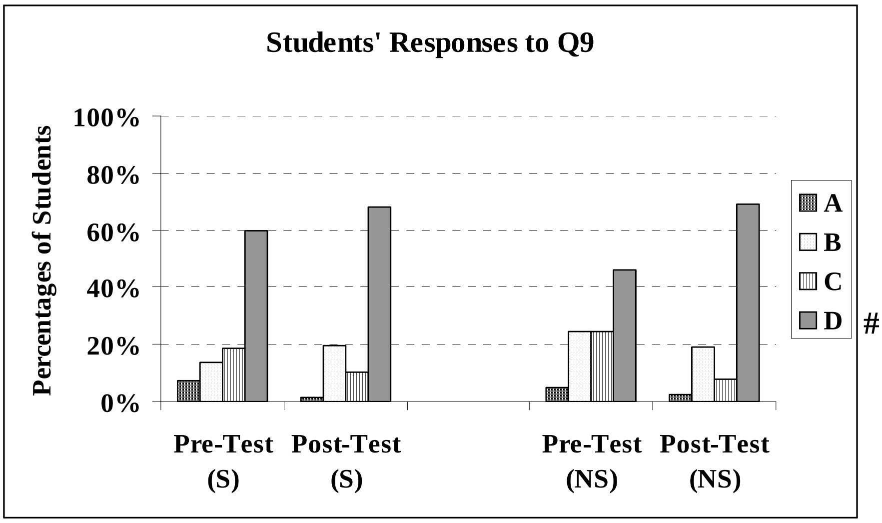
(A) I

(B) II

(C) V

(D) VI

Correct answer for Q10 is choice C.



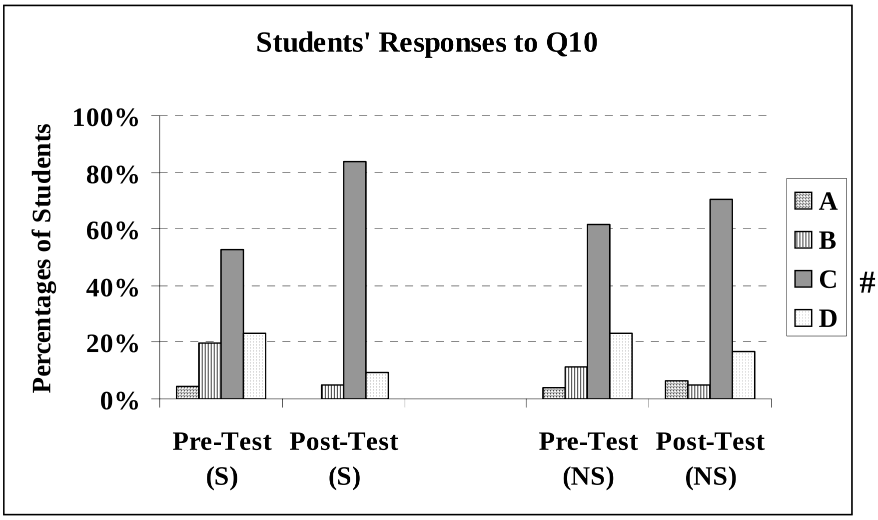


Figure 5.6: The percentages of science (S) and non-science (NS) students, who chose each choice of pre-and post-tests of the ECT in the concept of the earthquake causes (Q9 & Q10)

Q9 and Q10 showed a larger numbers of students, who correctly answered the questions in pre-and post-tests of the ECT, than other concepts. However, some alternative concepts, we found, were such as students believed that soil sliding and equator zone were factors influencing earthquakes (choice B of Q9). The interview results illustrated that most students thought that the equator zone was the warm or hot area, which could generate the volcano eruption causing earthquakes. Some said locating on islands was the correct answer (choice C of Q9, and choice B of Q10). In Q10, some students said they watched from TV and remembered that tsunamis often occurred in the Pacific Ocean, in particular, at the equator zone and islands such as Sumatra islands of Indonesia, and in Japan. These alternative conceptions slightly decreased after the earthquake classes.

5.4 Summary

Results from the previous chapter were discussed in this chapter. Our earthquake learning module, constructed following the key processes of the conceptual change approach, can be much more effective than lecture-based teaching method in enhancing conceptual understanding of earthquakes. Due to the impact of prior knowledge, this learning module was suitable for science students more than non-science. The teaching processes involving the concepts of speed of P-waves and Richter magnitude scale should be revised and looked in more details. Overall, alternative concepts were reduced after the finishing of the earthquake classes.

CHAPTER VI
CONCLUSIONS

The dissertation conclusion addresses the whole ideas of this research. The research questions, as mentioned in the first chapter, will be obviously responded. Then we will present the applications of this research for instruction, including its limitations. Eventually, the recommendations for further direction will be provided.

6.1 Summary of this Research

This research was organized to enhance Thai high school students understanding of earthquakes. The researchers have developed the new earthquake teaching module based on the 5-E models of an inquiry approach, including the pilot collected data. The module consisted of 6 subtopics of earthquakes namely; (1) causes of earthquakes, (2) exploring earthquakes in the world and in Thailand, (3) seismic waves, (4) the principle of seismographs, (5) locating the epicenter, and (6) magnitude and intensity of earthquakes. In each subtopic, we have provided both the lesson plan and its teaching tools. Examples of the teaching tools were the simple seismograph, the convection current demonstration set, the maps of earthquakes, volcanoes, plate boundaries, and sea-floor spreading, the slinky, worksheets and summary documents. We have built the assessment instrument called the Earthquake Concept Test (ECT). The questions of the ECT were developed from the Geoscience Concept Inventory (GCI), and the research based questions constructed by the researchers (Rakkapao et al, 2009). The 10 four-choice questions of the current version of the ECT consisted of the concepts of earthquake locations, particle motion at P-wave arrival, speed of P-waves, Richter magnitude scale, the relation among earthquakes, volcanoes, and plate boundaries, and earthquake causes. The validity and reliability tests of the ECT were vigorously determined via the Item-Objective Congruence Index (IOC index), the KR-21 reliability test, and the Item Response Theory (2PL model). We have tested the module with students, and modified it form the students' suggestions and experts' advice. Ultimately, we applied the teaching module of earthquakes with 245 tenth graders in two middle schools in the southern part of Thailand. The outcomes revealed that the students learning gain, from the instruction by using the new earthquake teaching module constructed by the researchers, was greater than that of the conventional instruction. Clearly, the normalized change showed in the middle region. Moreover, the satisfaction questionnaire results exhibited that more than 80% of these students agreed that they have learned the earthquakes from our teaching module. Overall, our earthquake teaching module was a profitably optional tool for earthquake teaching, for science based program students, in particular.

6.2 Answering the Research Questions

The following discussions aim to answer the research questions. We clearly illustrate both the question and its responses.

Research Question #1: What are the basic concepts of earthquakes for Thai high school students?

Answer:

Based on the act of legislation for the standard curriculum of national education Buddhist Era 2544, the earthquake is one of the main concepts in the 6^{th} strand of core science, called the earth changing process, for Thai high school students. The basic concepts of earthquakes are the definition and causes of earthquakes, earthquake strength, seismic waves, seismograph, earthquakes in Thailand, tsunamis, and safety procedure for earthquakes and their effects.

Research Question #2: What are Thai students' alternative concepts of earthquakes?

Answer:

We explored Thai students understanding of earthquakes by using the open-ended questions (n=342). Findings exposed some alternative concepts held by these students, as shown in the following table. Moreover, we have used the earthquake teaching module with students (n=245), including the interview; in this process we found some alternative concepts. The whole alternative concepts of earthquakes of Thai students found in this research were shown in table 6.1.

Table 6.1: The alternative concepts of earthquakes held by Thai students found in this research

Subtopics of Earthquakes	Alternative Concepts
1. Characteristics of earthquakes	1. All earthquakes create visible cracks on the earth's surface. 2. When an earthquake occurs, the earth shakes at least once every 10 seconds for a period of at least 1 minute. 3. All earthquakes damage manmade structures. 4. When an earthquake occurs, the gravitational pull of the earth increases.
2. Causes of earthquakes	5. Volcanic eruption is the main cause of earthquakes in Japan. 6. Earthquake occurrence depends on the topography. 7. Earthquakes often happen near the islands. 8. Earthquakes occur in rainy areas more than in dry areas. 9. Soil sliding and locating in the equator zone are the causes of earthquakes.
3. Earthquake strength	10. The ground moves up and down twice (0.33, 3, 10 and 20 times) as high for the 8 magnitude event as it did during the 6 magnitude.

Subtopics of Earthquakes	Alternative Concepts
	11. The seismic waves of the 8 Richter scale propagate faster than those of the magnitude 6 in the same homogeneous medium; since the former originates more severity (more vibration/more energy/ or more frequency) than the later one. 12. The seismic waves of the 6 Richter scale move faster than the magnitude 8 because it has low severity and high frequency.
4. Seismic waves	13. P-wave will shake the particle in a medium like that of water waves (waves on a string/ light/ microwaves/ radio waves/ or electromagnetic waves). 14. A medium's particle will spread in all directions (will move forward like a sine wave motion/ will vertically move back and forth/ will move forward/ or will go up) when P-waves arrive in the horizontal surface. 15. The speed of P-waves depended on the magnitude of earthquake (The larger the magnitudes are, the faster the P-waves move).
5. Tsunamis	16 Tsunamis often occur around the Pacific Ocean, since there are various islands and volcanic eruptions around it.
6. Seismographs	17. Particles move like the signal recorded on the seismogram when the P-wave arrives.

Research Question #3: Does the new teaching module (based on an inquiry approach) increase high school students' conceptual understanding of earthquakes?

Answer:

Yes, the teaching module increases student conceptual understanding of earthquakes. This is proved by the normalized change, as shown in the middle region.

6.3 Applications for Instruction

The researchers intended to design the efficiency teaching module of earthquakes for Thai students. Since, instructors and educators, who are interested, can apply the module in various options. These are;

(1) instructors can use this module to teach students in earthquakes classes,

(2) instructors can use the Earthquake Concept Test (ETC) to evaluate students understanding of such topics,

(3) instructors can take a question from the Earthquake Conceptual Survey or the ETC as a quiz in such an active learning classroom as peer instruction (Mazur, 1997),

(4) instructors can use the alternative concepts, found in this research, to set up a new teaching process, which is more suitable for their students, and

(5) instructors can use our teaching tool as a prototype for development a new one.

6.4 Limitations of this Research

Although this research is forcefully conducted and revised to achieve the statistically reliable study, here are some limitations.

(1) The teaching module is suitable for science based program students more than other groups. Instructors should modify again for using with non-science students.

(2) The teaching processes, involving the speed of P-waves and Richter magnitude scale, should be revised again.

(3) We collected data from groups of students in the southern and central parts of Thailand; since the alternative concepts, exhibited in the research, came from only those groups of students.

(4) Although the major work is constructing the teaching module, the development of the assessment instrument is a minor, the proper evaluation of the ECT is essential. Therefore, the ECT has been analyzed by using some standard statistical tests. There are many evaluation methods used in the education field, so it is possible that there are other methods which may be suitable for evaluation the ECT.

6.5 Recommendations for Further Research

The recommendations for further directions are the re-making the teaching process for the P-waves concept, and the development of the ECT to reach the standard assessment test of earthquakes. Moreover, modifying the teaching tools, such as a simple seismograph, to be a low cost instrument would be extremely interesting.

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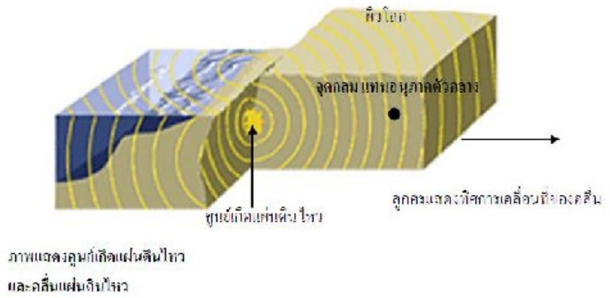
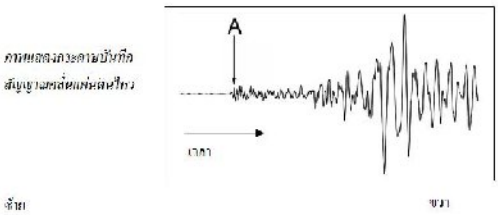
APPENDICES

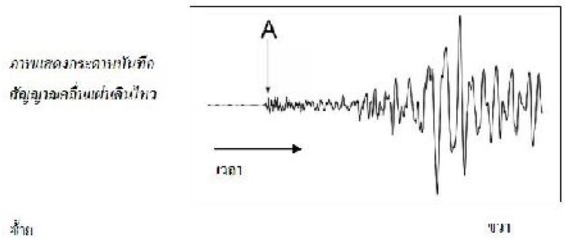
APPENDIX A
TABLE OF THE INDEX OF ITEM-OBJECTIVE CONGRUENCE (THE IOC INDEX)

ตารางพิจารณาความสอดคล้องระหว่างข้อสอบกับจุดประสงค์เชิงพฤติกรรม

คำชี้แจง ตารางนี้ออกแบบเพื่อให้ผู้เชี่ยวชาญพิจารณาว่าข้อสอบนั้นๆ วัดได้ตรงตามจุดประสงค์เชิงพฤติกรรมหรือไม่ โดย ถ้า ***"แน่ใจว่าตรง"*** ให้ทำเครื่องหมายในช่อง *" +1 "* แต่ถ้า ***"แน่ใจว่าไม่ตรง"*** ให้ทำเครื่องหมายในช่อง *" -1 "* และถ้า ***"ไม่แน่ใจว่าตรงหรือไม่"*** ให้ทำเครื่องหมายในช่อง *" 0 "*

จุดประสงค์เชิงพฤติกรรม	ข้อสอบ	การพิจารณา		
		+1	0	-1
1) สามารถอธิบายนิยามของแผ่นดินไหวได้	1. คำอธิบายใดต่อไปนี้ที่นักวิทยาศาสตร์หมายความถึง เมื่อกล่าวถึงคำว่า " แผ่นดินไหว " **เลือกได้มากกว่า 1 คำตอบ** (A) แผ่นดินไหวทุกครั้งทำให้เกิดรอยแยกที่มองเห็นได้บนพื้นผิวโลก (B) เมื่อเกิดแผ่นดินไหว โลกสั่นอย่างน้อย 1 ครั้งในทุกๆ 10 วินาที และสั่นอยู่นานอย่างน้อย 1 นาที (C) แผ่นดินไหวทุกครั้งทำลายสิ่งปลูกสร้างที่คนสร้างขึ้น (D) เมื่อเกิดแผ่นดินไหว พลังงานถูกปล่อยจากภายในโลก (E) เมื่อเกิดแผ่นดินไหว แรงดึงดูดที่กระทำต่อโลกมีมากขึ้น			
2) สามารถอธิบายสาเหตุของการเกิดแผ่นดินไหวได้	2) ประเทศไทย และประเทศญี่ปุ่น มีความเสี่ยงต่อการเกิดแผ่นดินไหวเท่ากันหรือไม่ เพราะอะไร			
	3) บริเวณที่มีฝนตกชุกมีความเสี่ยงต่อการเกิดแผ่นดินไหวมากกว่าบริเวณที่แห้งแล้งหรือไม่ เพราะอะไร			
	คำชี้แจง ข้อ 9 ให้ใช้ข้อมูล I-VI ตอบคำถาม I เกิดดินถล่ม IV อยู่ในแนวรอยเลื่อนที่มีพลัง II มีภูมิประเทศเป็นเกาะ V อยู่ตรงรอยต่อของแผ่นธรณีภาค III มีการระเบิดของภูเขาไฟ VI มีตำแหน่งอยู่ใกล้แนวศูนย์สูตร 9) ปัจจัยใดบ้างที่เป็นสาเหตุของการเกิดแผ่นดินไหวของโลก **(ตอบได้มากกว่าหนึ่งคำตอบ)**			
3) สามารถอธิบายเกี่ยวกับปรากฏการณ์แผ่นดินไหวในประเทศไทยได้	2) ประเทศไทย และประเทศญี่ปุ่น มีความเสี่ยงต่อการเกิดแผ่นดินไหวเท่ากันหรือไม่ เพราะอะไร			
4) สามารถอธิบายเกี่ยวกับมาตราวัดขนาดแผ่นดินไหวได้	5) แผ่นดินไหวขนาด 6 กับ 8 ตามมาตราริกเตอร์ ทำให้**อนุภาคดินสั่นต่างกันกี่เท่า**			

จุดประสงค์เชิงพฤติกรรม	ข้อสอบ	การพิจารณา		
		+1	0	-1
	6) แผ่นดินไหวขนาด 6 กับ 8 ตามมาตราริกเตอร์ ถ้าเกิดขึ้น ณ ศูนย์เกิดแผ่นดินไหวเดียวกัน ในการเดินทางของคลื่นผ่านดินที่เหมือนกันทุกประการไปยังสถานีตรวจวัดแผ่นดินไหวแห่งหนึ่ง อยากทราบว่า คลื่นแผ่นดินไหวขนาดใดที่ใช้เวลาเดินทางมาถึงสถานีน้อยกว่ากัน เพราะอะไร			
5) สามารถอธิบายเกี่ยวกับคลื่นแผ่นดินไหวได้	4) เมื่อคลื่นแผ่นดินไหวคลื่นแรกเคลื่อนที่ผ่านตัวกลาง เช่น ดิน หิน จะทำให้เกิดการสั่นของอนุภาคตัวกลาง ซึ่งมีลักษณะคล้ายคลึงกับการสั่นของตัวกลางคลื่นใด			
	6) แผ่นดินไหวขนาด 6 กับ 8 ตามมาตราริกเตอร์ ถ้าเกิดขึ้น ณ ศูนย์เกิดแผ่นดินไหวเดียวกัน ในการเดินทางของคลื่นผ่านดินที่เหมือนกันทุกประการไปยังสถานีตรวจวัดแผ่นดินไหวแห่งหนึ่ง อยากทราบว่า คลื่นแผ่นดินไหวขนาดใดที่ใช้เวลาเดินทางมาถึงสถานีน้อยกว่ากัน เพราะอะไร			
	7) จากภาพด้านล่าง กำหนดทิศการเคลื่อนที่ของคลื่นแผ่นดินไหวเป็นตามลูกศร ขณะที่คลื่นแผ่นดินไหวคลื่นแรกเคลื่อนที่ผ่านตัวกลาง (เช่น ดิน หิน) **<u>ให้วาดลักษณะการเคลื่อนที่ของอนุภาคตัวกลางลงบนจุดกลม</u>** ( ) ด้านล่าง ซึ่งแทนอนุภาคตัวกลาง  8) จากภาพด้านล่าง A เป็นตำแหน่งของสัญญาณคลื่นแผ่นดินไหวแรกที่บันทึกได้ ถ้ากำหนดให้คลื่นแผ่นดินไหวเดินทางจากซ้ายไปขวาของกระดาษ คลื่นแผ่นดินไหวแรกที่บันทึกได้บนกระดาษนี้ทำให้**<u>อนุภาคตัวกลาง เช่น ดิน หินเคลื่อนที่อย่างไร</u>** ●  			

<table>
<tr><th rowspan="2">จุดประสงค์เชิงพฤติกรรม</th><th rowspan="2">ข้อสอบ</th><th colspan="3">การพิจารณา</th></tr>
<tr><th>+1</th><th>0</th><th>-1</th></tr>
<tr><td>6) สามารถอธิบายหลักการทำงานของเครื่องมือวัดแผ่นดินไหว (Seismograph) ได้</td><td>8) จากภาพด้านล่าง A เป็นตำแหน่งของสัญญาณคลื่นแผ่นดินไหวแรกที่บันทึกได้ ถ้ากำหนดให้คลื่นแผ่นดินไหวเดินทางจากซ้ายไปขวาของกระดาษ คลื่นแผ่นดินไหวแรกที่บันทึกได้บนกระดาษนี้ทำให้<u>อนุภาคตัวกลาง เช่น ดิน หิน เคลื่อนที่อย่างไร</u>

</td><td></td><td></td><td></td></tr>
<tr><td>7) สามารถอธิบายเกี่ยวกับการเกิดสึนามิ (Tsunamis) ได้</td><td><u>คำชี้แจง</u> ข้อ 10 ให้ใช้ข้อมูล I-VI ตอบคำถาม
I เกิดดินถล่ม   IV อยู่ในแนวรอยเลื่อนที่มีพลัง
II มีภูมิประเทศเป็นเกาะ   V อยู่ตรงรอยต่อของแผ่นธรณีภาค
III มีการระเบิดของภูเขาไฟ   VI มีตำแหน่งอยู่ใกล้แนวศูนย์สูตร

10) เพราะเหตุใดคลื่นสึนามิจึงมักเกิดขึ้นบริเวณมหาสมุทรแปซิฟิก <u>(ตอบได้มากกว่าหนึ่งคำตอบ)</u></td><td></td><td></td><td></td></tr>
</table>

ความคิดเห็นเพิ่มเติม

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ลงชื่อ... ผู้เชี่ยวชาญ

(...)

ตำแหน่ง..

APPENDIX B
THE EARTHQUAKE CONCEPTUAL SURVEY
(THAI VERSION)

คำชี้แจง

1. แบบสำรวจความเข้าใจนี้เป็นส่วนหนึ่งของงานวิจัยเพื่อพัฒนาความเข้าใจเรื่องแผ่นดินไหว สำหรับนักเรียน/นักศึกษาในประเทศไทย
2. คำถามมีจำนวน 10 ข้อ (3 หน้า) ให้ผู้ตอบแบบสำรวจเขียนตอบลงในช่องว่างที่เตรียมไว้ และใช้เวลาทำประมาณ 20 นาที
3. ผู้วิจัยขอความร่วมมือให้ทุกท่านตอบคำถามทุกข้ออย่างเต็มความสามารถ โดยข้อมูลที่ได้ไม่มีผลต่อคะแนนและวิชาเรียนของผู้ตอบแบบสำรวจแต่อย่างใด

ข้าพเจ้ายินดีให้ความร่วมมือในการตอบแบบสำรวจความเข้าใจ เรื่องแผ่นดินไหว

ลงชื่อ..

(..)

1. คำอธิบายใดต่อไปนี้ที่นักวิทยาศาสตร์หมายความถึง เมื่อกล่าวถึงคำว่า “แผ่นดินไหว”

<u>เลือกได้มากกว่า 1 คำตอบ</u>

(A) แผ่นดินไหวทุกครั้งทำให้เกิดรอยแยกที่มองเห็นได้บนพื้นผิวโลก

(B) เมื่อเกิดแผ่นดินไหว โลกสั่นอย่างน้อย 1 ครั้งในทุกๆ 10 วินาที และสั่นอยู่นานอย่างน้อย 1 นาที

(C) แผ่นดินไหวทุกครั้งทำลายสิ่งปลูกสร้างที่คนสร้างขึ้น

(D) เมื่อเกิดแผ่นดินไหว พลังงานถูกปล่อยจากภายในโลก

(E) เมื่อเกิดแผ่นดินไหว แรงดึงดูดที่กระทำต่อโลกมีมากขึ้น

2. ประเทศไทย และประเทศญี่ปุ่น มีความเสี่ยงต่อการเกิดแผ่นดินไหวเท่ากันหรือไม่ เพราะอะไร

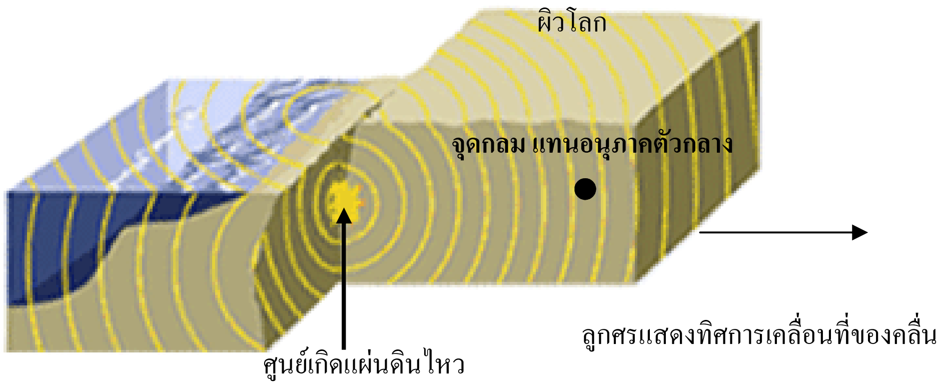
3.บริเวณที่มีฝนตกชุกมีความเสี่ยงต่อการเกิดแผ่นดินไหวมากกว่าบริเวณที่แห้งแล้งหรือไม่ เพราะอะไร

4. เมื่อคลื่นแผ่นดินไหวคลื่นแรกเคลื่อนที่ผ่านตัวกลาง เช่น ดิน หิน จะทำให้เกิดการสั่นของอนุภาคตัวกลาง ซึ่งมีลักษณะคล้ายคลึงกับการสั่นของตัวกลางคลื่นใด

5. แผ่นดินไหวขนาด 6 กับ 8 ตามมาตราริกเตอร์ ทำให้**<u>อนุภาคดินสั่นต่างกัน</u>**กี่เท่า

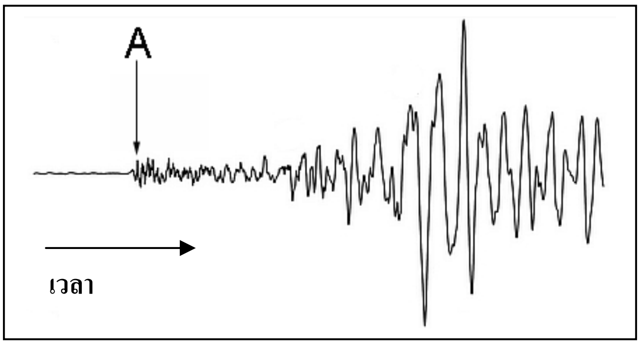
6. แผ่นดินไหวขนาด 6 กับ 8 ตามมาตราริกเตอร์ ถ้าเกิดขึ้น ณ ศูนย์เกิดแผ่นดินไหวเดียวกัน ในการเดินทางของคลื่นผ่านดินที่เหมือนกันทุกประการไปยังสถานีตรวจวัดแผ่นดินไหวแห่งหนึ่ง อยากทราบว่า คลื่นแผ่นดินไหวขนาดใดที่ใช้เวลาเดินทางมาถึงสถานีน้อยกว่ากัน เพราะอะไร

7. จากภาพด้านล่าง กำหนดทิศการเคลื่อนที่ของคลื่นแผ่นดินไหวเป็นตามลูกศร ขณะที่คลื่นแผ่นดินไหวคลื่นแรกเคลื่อนที่ผ่านตัวกลาง (เช่น ดิน หิน) ให้**วาดลักษณะการเคลื่อนที่ของอนุภาคตัวกลางลงบนจุดกลม (●) ด้านล่างซึ่งแทนอนุภาคตัวกลาง**



8. จากภาพด้านล่าง **A** เป็นตำแหน่งของสัญญาณคลื่นแผ่นดินไหวแรกที่บันทึกได้ ถ้ากำหนดให้คลื่นแผ่นดินไหวเดินทางจากซ้ายไปขวาของกระดาษ คลื่นแผ่นดินไหวแรกที่บันทึกได้บนกระดาษนี้ทำให้**<u>อนุภาคตัวกลาง เช่น ดิน หิน เคลื่อนที่อย่างไร</u>**

ซ้าย



ขวา

คำตอบ

<u>คำชี้แจง</u> ข้อ 9 และ ข้อ 10 ให้ใช้ข้อมูล I - VI ตอบคำถาม

I เกิดดินถล่ม	**IV** อยู่ในแนวรอยเลื่อนที่มีพลัง
II มีภูมิประเทศเป็นเกาะ	**V** อยู่ตรงรอยต่อของแผ่นธรณีภาค
III มีการระเบิดของภูเขาไฟ	**VI** มีตำแหน่งอยู่ใกล้แนวศูนย์สูตร

9. ปัจจัยใดบ้างที่เป็นสาเหตุของการเกิดแผ่นดินไหวของโลก **(ตอบได้มากกว่าหนึ่งคำตอบ)**

10. เพราะเหตุใดคลื่นสึนามิจึงมักเกิดขึ้นบริเวณมหาสมุทรแปซิฟิก **(ตอบได้มากกว่าหนึ่งคำตอบ)**

APPENDIX C
THE EARTHQUAKE CONCEPTUAL SURVEY
(ENGLISH VERSION)

Description:

1. This survey is a part of the education research to promote Thai students understanding of earthquakes.
2. This survey consists of 10 questions (3 pages). The volunteer students should respond in the blank of each question, and take around 20 minutes to complete the survey.
3. Please answer the following questions to the best of your ability. No information of the answers will be given to instructors or assessing the course.

I agree to participate in this study.

Signature...

(...)

1. Which of the following describes what scientists mean when they use the word "an earthquake". **Choose all that apply.**

(A) All earthquakes create visible cracks on the Earth's surface.

(B) When an earthquake occurs, the earth shakes at least once every 10 seconds for a period of at least 1 minute.

(C) All earthquakes damage man-made structures.

(D) When an earthquake occurs, energy is released from inside the Earth.

(E) When an earthquake occurs, the gravitational pull of the Earth increases.

2. Do earthquakes occur in Thailand more than in Japan? Why?

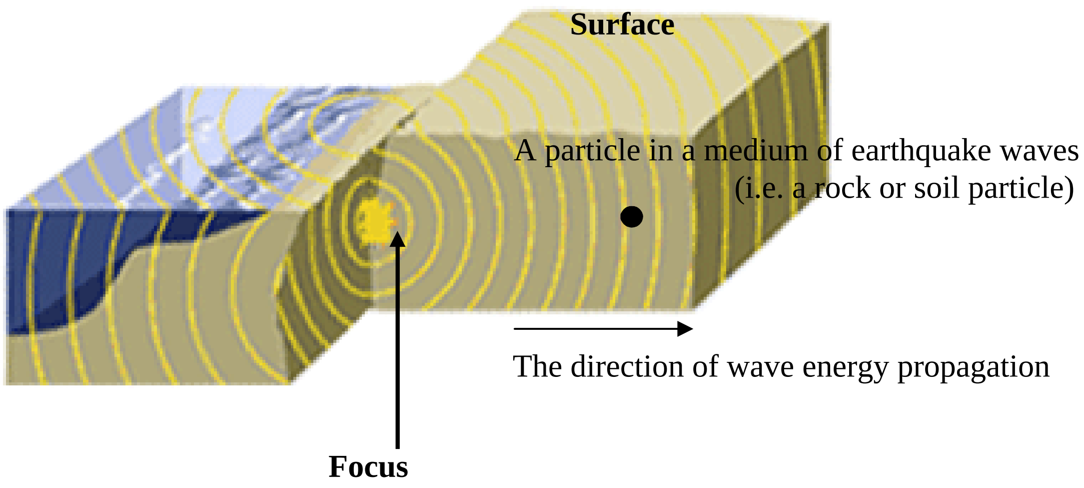
3. Do earthquakes occur in rainy areas more than in dry areas? Why?

4. When the first earthquake wave (P-wave) propagates through a soil or rock particle, it will shake the particle like what other kinds of waves?

5. What is the ratio of the ground vibration amplitude of 8 Richter magnitude scale to that of 6 Richter magnitude scale?

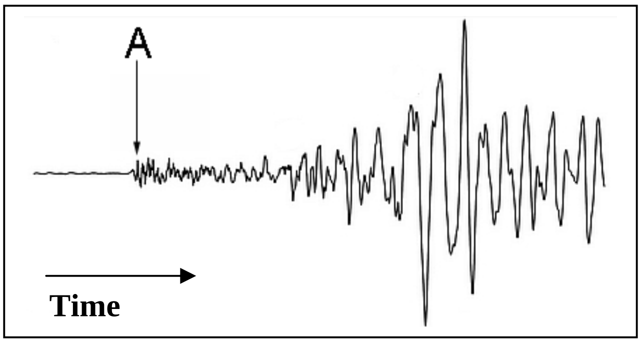
6. If 6 and 8 Richter magnitude earthquakes occur at the same station, and the seismic waves of them propagate through homogeneous medium in the same pathway to the same seismic station, which one (6 or 8 Richter scales of earthquakes) takes less time to reach the seismic station? Why?

7. Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot "●" in the following figure). **Draw the particle motion (at the dot)** when the first earthquake wave (P-wave) arrives. (The direction of wave energy propagation is shown by the arrow below)



8. Consider the position A on the following seismogram. It is the first earthquake wave signal recorded on the seismogram. Assume that the direction of wave energy propagation is from the left to the right hand side of the figure; **describe the particle motion** when the first earthquake wave (P-wave) arrives.

Left



Right

Answer

Description: Choose I-VI to complete Q9 and Q10

I	Soil Sliding	IV	Active Faults
II	Islands	V	Plate Boundaries
III	Volcanic Eruption	VI	Equator Zone

9. Which factors are the causes of earthquakes? ***(Choose all that apply)***

10. Why do tsunamis often occur along the margins of the Pacific Ocean?

(Choose all that apply)

APPENDIX D
THE EARTHQUAKE LEARNING MODULE

We introduce the lesson plans and teaching tools of our earthquake learning module. This learning module is based on the act of legislation for the standard curriculum of national education Buddhist Era 2544. The earthquake concept is a core science concept in the 6^{th} strand or the earth changing process. It is provided for Thai high school students. Overall, after the finishing of the instruction of this topic, the expected outcomes are;

(1) students are able to do experiment from the artificial situations to discuss the causes and process of earthquakes,

(2) students are able to do experiment from the artificial situations to discuss the seismic waves and their effect,

(3) students are able to explore and discuss about the earthquakes of the world,

(4) students are able to search, collect and discuss about the earthquake events, its magnitude and intensity scales, and

(5) students are able to search, collect and discuss about earthquake phenomena and its effect in Thailand.

It is divided into 6 lesson plans taking 300 minutes (50 minutes for each lesson plan), namely;

Lesson Plan 1: The causes of earthquakes

Lesson Plan 2: Explore earthquakes in the world and in Thailand

Lesson Plan 3: Seismic Waves

Lesson Plan 4: The principle of seismographs

Lesson Plan 5: Locate the epicenter

Lesson Plan 6: Magnitude and intensity of earthquakes

We developed a lesson plan that consists of objectives, teaching tools and teaching process that based on the 5-E model of the inquiry-based learning method. The six lesson plans will be introduced in the following.

Lesson Plan 1: The Causes of Earthquakes

1.1 Objectives

To demonstrate the mantle convection current and the plate movement by using the demonstration set to challenge students to connect with the causes and process of earthquakes and their effects.

1.2 Times 50 minutes

1.3 Teaching Tools

(1) The convection current demonstration set

(2) Earthquake documentary videos

(3) A4 Papers

(4) Scotch tape

(5) Worksheet 1: The Cause of Earthquakes

(6) Summary document 1: The Cause of Earthquakes

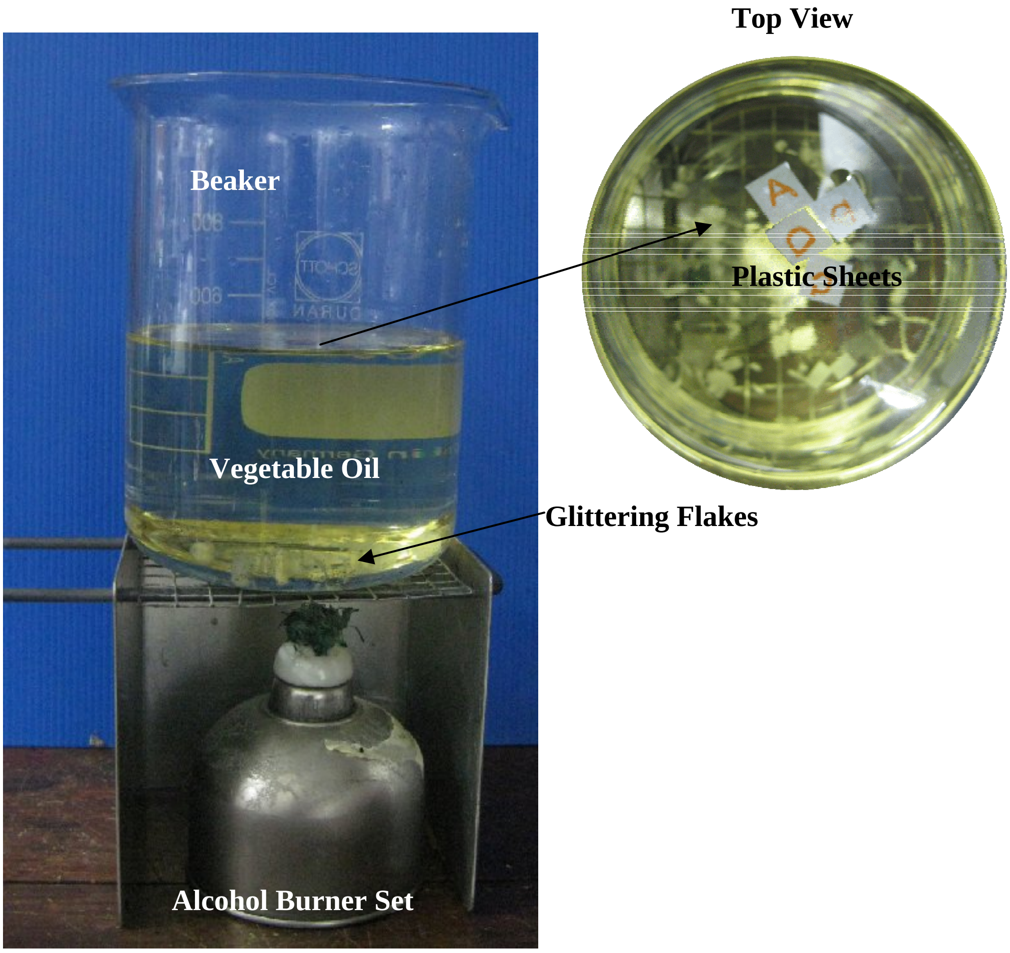
(7) Lecture power point

1.4 Teaching Processes

The 5-E model of the inquiry-based learning method	**Times (minutes)**	**Activities**
Step 1: Engagement	10	1) Students watch earthquake videos, and discuss about what happen, why, and did you have an experience in an earthquake. 2) Students answer 2 questions in the blank papers and stick the answers on the board in front of the class. **Q1**: What are the causes of earthquakes? **Q2**: Do earthquakes occur in rainy areas more than in dry areas? Why? 3) The instructor groups students' answers of the two questions.

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 2: Exploration	20	4) The instructor demonstrates the convection current set. 5) Students discuss the demonstration and connect ideas to the cause of plate movement of the earth. 6) Students fill out the worksheet 1 to summarize their own concept about the causes of plate movement and their effects.
Step 3: Explanation	10	7) Students gently push two papers to hit each other on a table. 8) Students discuss the demonstration and connect ideas to causes and process of earthquakes. 9) Students complete the worksheet 1. 10) The instructor shows the animations of 3 types of the plate movement (convergence, divergence, and transform) and the process of earthquakes.
Step 4: Elaboration	5	11) The instructor describes about the average rate of plate movement in a year. 12) Students and the instructor discuss the volcanic eruption, nuclear explosion, and meteorite impact, which can generate the earthquakes. 13) Students and the instructor discuss the occurrence of the Himalayan mountain range, the San Andreas fault, and the sea floor spreading.
Step 5: Evaluation	5	14) Back to the students' answers to Q1 and Q2 students identify and discuss the groups of correct answers for both questions.

The convection current demonstration set



Applications for Instruction

1. Use the convection current demonstration set with worksheet 1
2. Starting, add glittering flakes in the vegetable oil containing in the beaker putting on the alcohol burner set. Then ask students to predict what happen if the burner is burned up. Students predict in the worksheet. After that the convection current demonstration set is shown. Students discuss the convection current in the mantle of the earth and note in the worksheet.

3. Again, put the plastic sheets on the surface of the vegetable oil. Then ask students to predict what happen if the burner is burned up. Students predict in the worksheet. After that the convection current demonstration set is shown. Students discuss and note in the worksheet.
4. By using the set, students discuss the cause of plate movement and the causes and process of earthquakes.
5. Students summarize own ideas into the worksheet and study again from the summary document.

ใบงานที่ 1 เรื่อง สาเหตุการเกิดแผ่นดินไหว

ชื่อ..นามสกุล.........................

ชั้น................เลขที่.....................

ทำนาย

1. ให้นักเรียน**ทำนาย** **(a)** ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน (ดูจากกากเพชร) ซึ่งเขียนแทนด้วยจุด ● และ **(b)** การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน หลังจุดตะเกียงแอลกอฮอล์ โดยให้**วาดลูกศรลงในรูปชุดสาธิต**ด้านล่าง

รูปชุดสาธิต

(b) การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน

(a) ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน

คำตอบ

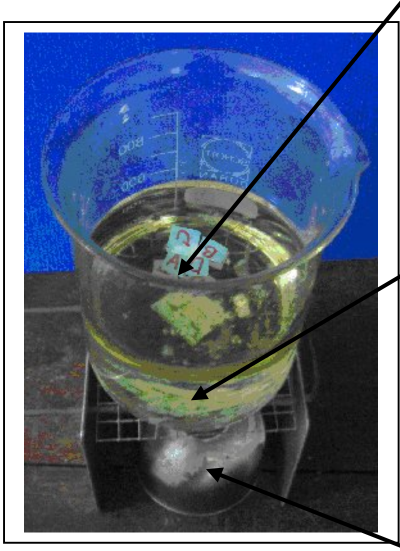
2. ให้นักเรียน**บันทึกสิ่งที่เห็นจากชุดสาธิต** **(a)** ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน (ดูจากกากเพชร) ซึ่งเขียนแทนด้วยจุด ● และ **(b)** การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน หลังจุดตะเกียงแอลกอฮอล์ โดยให้**วาดลูกศรลงในรูปชุดสาธิต**ด้านล่าง

รูปชุดสาธิต

(b) การเปลี่ยนแปลงของแผ่นพลาสติกที่ลอยอยู่บนน้ำมัน

(a) ลักษณะการเคลื่อนที่ของอนุภาคน้ำมัน

3. ให้นักเรียนเลือกโครงสร้างโลก ได้แก่ **แผ่นเปลือกโลก, เนื้อโลก และ แก่นโลก** เติมลงในช่องว่างที่ตรงกับวัสดุของชุดสาธิตที่จำลองสมบัติทางกายภาพของโครงสร้างโลกได้อย่างสอดคล้อง พร้อมบอกเหตุผล



รูปชุดสาธิต

แผ่นพลาสติก	
ทำนาย	คำตอบ

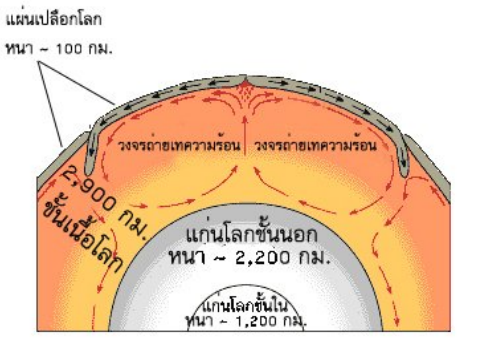
น้ำมัน	
ทำนาย	คำตอบ

ความร้อนจากตะเกียงแอลกอฮอล์	
ทำนาย	คำตอบ

4. จากชุดสาธิต ให้นักเรียน**<u>เขียนอธิบาย</u>**สาเหตุการเคลื่อนที่ของแผ่นเปลือกโลก

ใบความรู้ที่ 1 เรื่อง สาเหตุการเกิดแผ่นดินไหว

โครงสร้างโลกชั้นเปลือกโลก (Crust) และลึกลงไปถึงชั้นเนื้อโลกส่วนบน (Upper Mantle) มีลักษณะเป็นของแข็ง สองชั้นนี้ถูกเรียกรวมกันว่า ชั้นธรณีภาค (Lithosphere) โดยชั้นธรณีภาคนี้จะแตกออกเป็นแผ่นๆ เราเรียกแต่ละแผ่นว่า **เพลต (Plate)** (แผ่นธรณีภาค หรือแผ่นเปลือกโลก) แผ่นเปลือกโลกนี้ลอยตัวอยู่บน ชั้นฐานธรณีภาค (Asthenosphere) ซึ่งมีสถานะเป็นของแข็ง แต่เนื่องจากอุณหภูมิที่สูงมาก จึงทำให้ของแข็งนี้ไหลได้ (นักวิทยาศาสตร์เรียกมันว่า เป็นสภาพพลาสติก (Plastic-like))

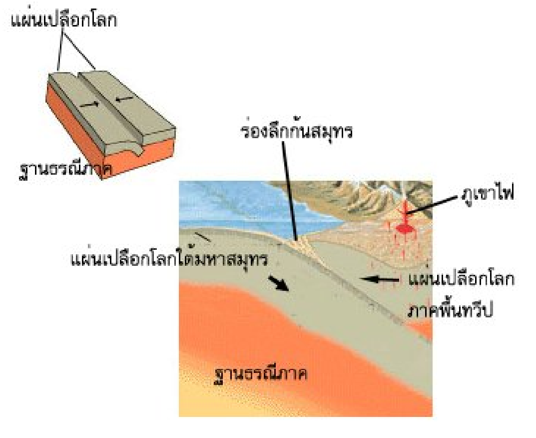
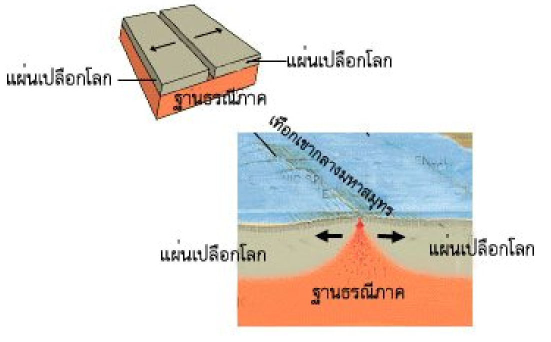


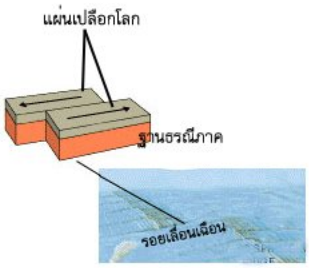
(อ้างอิง: http://pubs.usgs.gov/gip/dynamic/unanswered.html)

รูปที่ 1.1 วงจรถ่ายเทความร้อนในชั้นเนื้อโลก (Mantle Convection Current)

เนื่องจากความร้อนจากชั้นแก่นโลก (Core) มีการถ่ายเทสู่ชั้นเนื้อโลก (Mantle) สสารที่ได้รับความร้อนจึงขยายตัวแล้วลอยขึ้น เมื่อถึงข้างบนที่มีอุณหภูมิต่ำกว่า มันจะหดตัวแล้วจมลง นักวิทยาศาสตร์เชื่อว่าการลอยตัวขึ้นและจมลงของสสารในชั้นเนื้อโลกเกิดขึ้นตลอดเวลาเป็นวงจรถ่ายเทความร้อน (Mantle Convection Current) โดยเชื่อกันว่าการวนครบหนึ่งรอบใช้เวลาประมาณ 200 ล้านปี การเคลื่อนตัวของสสารนี้เองที่จะพาเอาแผ่นเปลือกโลกที่ลอยอยู่ด้านบนมันให้เคลื่อนที่ตามไปด้วย (รูปที่ 1.1) แต่อย่างไรก็ตามนักวิทยาศาสตร์บางกลุ่มเชื่อว่าวงจรถ่ายเทความร้อนนี้เกิดขึ้นในชั้นฐานธรณีภาค

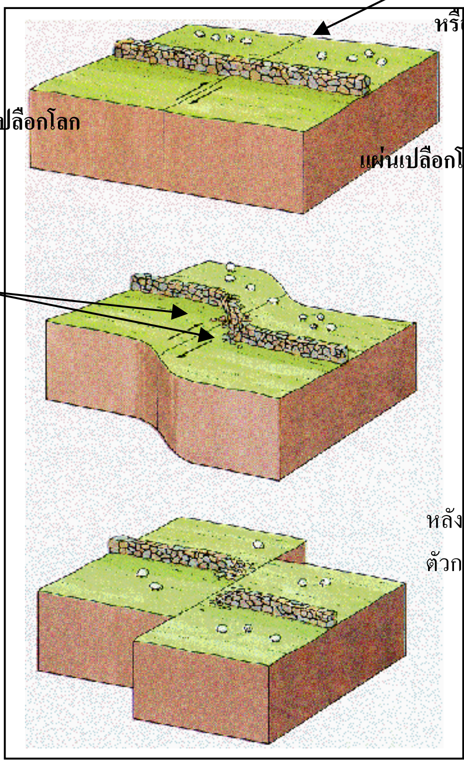
การเคลื่อนที่ของแผ่นเปลือกโลกตรงบริเวณรอยต่อ มี 3 แบบ ดังนี้

ชนิด	รูปภาพที่ 1.2 แสดงการเคลื่อนที่ของแผ่นเปลือกโลก	ลักษณะภูมิประเทศที่เกิดขึ้น
1. แผ่นเปลือกโลกที่เคลื่อนที่เข้าหากัน (Convergent Plates)		แนวภูเขาไฟกลางมหาสมุทร ร่องลึกก้นสมุทร (Trench/Arc) เทือกเขาบนแผ่นเปลือกโลกภาคพื้นทวีป (Collisional Mountain Ranges) เช่น เทือกเขาหิมาลัย เทือกเขาแอลป์
2. แผ่นเปลือกโลกที่เคลื่อนที่ออกจากกัน (Divergent Plates)		เทือกเขากลางมหาสมุทร (Mid-Ocean Ridge) หุบเขาทรุด (Rift Valley)

ชนิด	รูปภาพแสดงการเคลื่อนที่ของแผ่นเปลือกโลก	ลักษณะภูมิประเทศที่เกิดขึ้น
3. แผ่นเปลือกโลกที่เคลื่อนที่ผ่านกัน (Transform Plates)		แนวรอยเลื่อน (Fault) เช่น รอยเลื่อนซาน แอนเดรียส (San Andreas fault)

(อ้างอิง: http://www.kidsgeo.com/geology-for-kids/)

การเคลื่อนที่ของแผ่นเปลือกโลกแต่ละแผ่น อาจจะทำให้เกิดการชนกัน แยกออกจากกัน หรือเคลื่อนที่ผ่านกัน ตรงบริเวณรอยต่อของแผ่นเปลือกโลกแต่ละคู่ที่ติดกัน เช่น แผ่นเปลือกโลกอินโด-ออสเตรเลียนเคลื่อนที่เข้าชนแผ่นเปลือกโลกยูเรเซียน การเคลื่อนที่เข้าหากันนี้ ทำให้เกิดการผลักกันและค่อยๆโค้งงอ เวลานานเข้าเกิดเป็นบริเวณที่เราเรียกว่าเทือกเขาหิมาลัยนั่นเอง สำหรับแผ่นเปลือกโลกคู่ใดที่เคลื่อนที่เข้าหากันนั้น ก็จะเกิดการโค้งงอของแผ่นเปลือกโลกเพิ่มขึ้นเรื่อยๆ (โดยเฉลี่ยแผ่นเปลือกโลกเคลื่อนที่ได้ระยะทางประมาณ 3-5 เซนติเมตรในหนึ่งปี) พร้อมกับการสะสมพลังงานในชั้นดิน หิน เมื่อแผ่นเปลือกโลกโค้งงอจนถึงขีดจำกัดที่มันจะเกิดได้ (หรืออาจกล่าวว่า แผ่นเปลือกโลกเก็บสะสมพลังงานไว้มากจนถึงขีดจำกัดที่มันจะกักเก็บได้) มันก็จะเกิดการดีดตัวอย่างรวดเร็วเพื่อกลับสู่สภาพปกติ (คืนตัว) ทำให้เกิดการสั่นสะเทือนของพื้นดิน เราเรียกปรากฏการณ์ที่เกิดขึ้นนี้ว่า **แผ่นดินไหว (Earthquakes)** พลังงานที่เคยกักเก็บไว้ถูกแผ่ออกมาในรูปของคลื่น เราเรียกว่า **คลื่นไหวสะเทือน** หรือ**คลื่นแผ่นดินไหว (Seismic Waves)** โดยทฤษฎีที่อธิบายสาเหตุการเกิดแผ่นดินไหวตามธรรมชาตินี้ คือ **ทฤษฎีการคืนตัวของวัตถุ (Elastic Rebound Theory)** (รูปที่ 1.3) นอกจากนี้แผ่นดินไหวอาจเกิดจากการระเบิดของภูเขาไฟ หรือการกระทำของมนุษย์ เช่น การระเบิด เครื่องขุดเจาะหิน แต่คลื่นไหวสะเทือนที่เกิดขึ้นเหล่านี้จะมีขนาดเล็ก



รูปที่ 1.3 ทฤษฎีการคืนตัวของวัตถุ
(Elastic Rebound Theory)

(อ้างอิง: http://ww2.lafayette.edu/~malincol/Geol120/earthquaketopics.html)

Lesson Plan 2: Exploring Earthquakes in the World and in Thailand

2.1 Objectives

(1) Students are able to identify the earthquake regions of the world.

(2) Students are able to discuss the relation between plate boundaries, earthquakes and volcano positions, and sea-floor spreading.

(3) Students are able to discuss the earthquake risk areas in Thailand.

2.2 Times 50 minutes

2.3 Teaching Tools

(1) The world maps of plate boundaries (A), earthquake positions (B), volcano positions (C) and sea-floor spreading (D)

(2) The map of active faults in Thailand

(3) Historical data of earthquake occurrence in Thailand

(4) Summary document 2: Earthquake Regions of the world and Thailand

(5) Lecture power point

2.4 Teaching Processes

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 1: Engagement	5	(1) The teacher briefly summarizes the concept of the causes of earthquakes, from the last period again. (2) Students watch the earthquake movies and discuss.
Step 2: Exploration	25	(3) Students, in a group of 3-4 students, seek for the relation between plate boundaries, earthquakes and volcano locations, and sea-floor spreading by overlapping the map A, B, C, and D. Each group discusses what they have found with other groups.

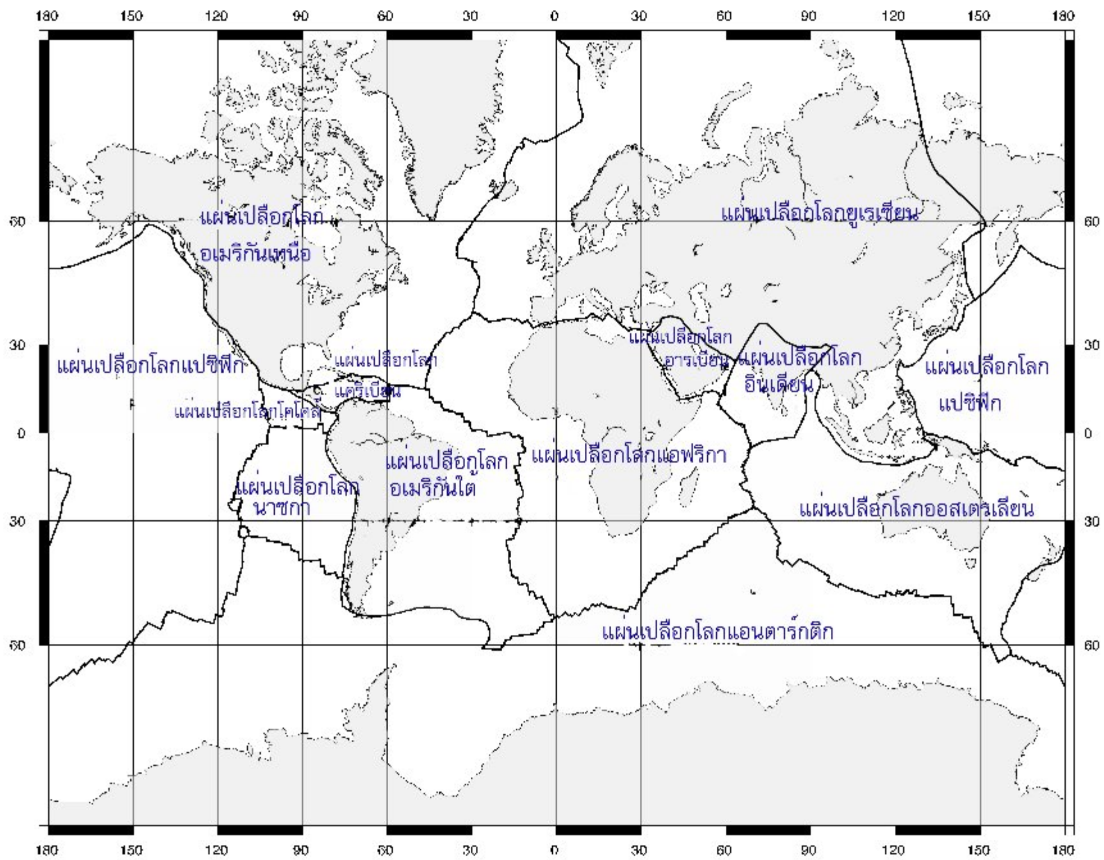
The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 3: Explanation	5	(4) Students in class discuss the relation between plate boundaries, earthquakes and volcano positions, and sea-floor spreading.
Step 4: Elaboration	10	(5) Students plot the historical earthquake positions in the map of active faults in Thailand. (6) Students study about the earthquake risk areas in Thailand. (7) The teacher and students discuss the earthquake regions of the World and of Thailand
Step 5: Evaluation	5	(8) Students conclude what they have learned.

The world maps of the plate boundaries (A), the earthquake locations (B), the volcano locations (C) and the sea-floor spreading (D), including the map of active faults in Thailand are shown in the following.

Applications for Instruction

1. Copy maps A, B, C and D into the transparent slides, and gives them to students (a set for a group), coupled with the A4 papers.
2. Students overlap the maps on the paper to explore the relation between plate boundaries, earthquakes and volcano locations, and sea-floor spreading.
3. Students plot the historical earthquake location data in the map of active faults in Thailand, and study what they have found.
4. Students study again from the summary document.

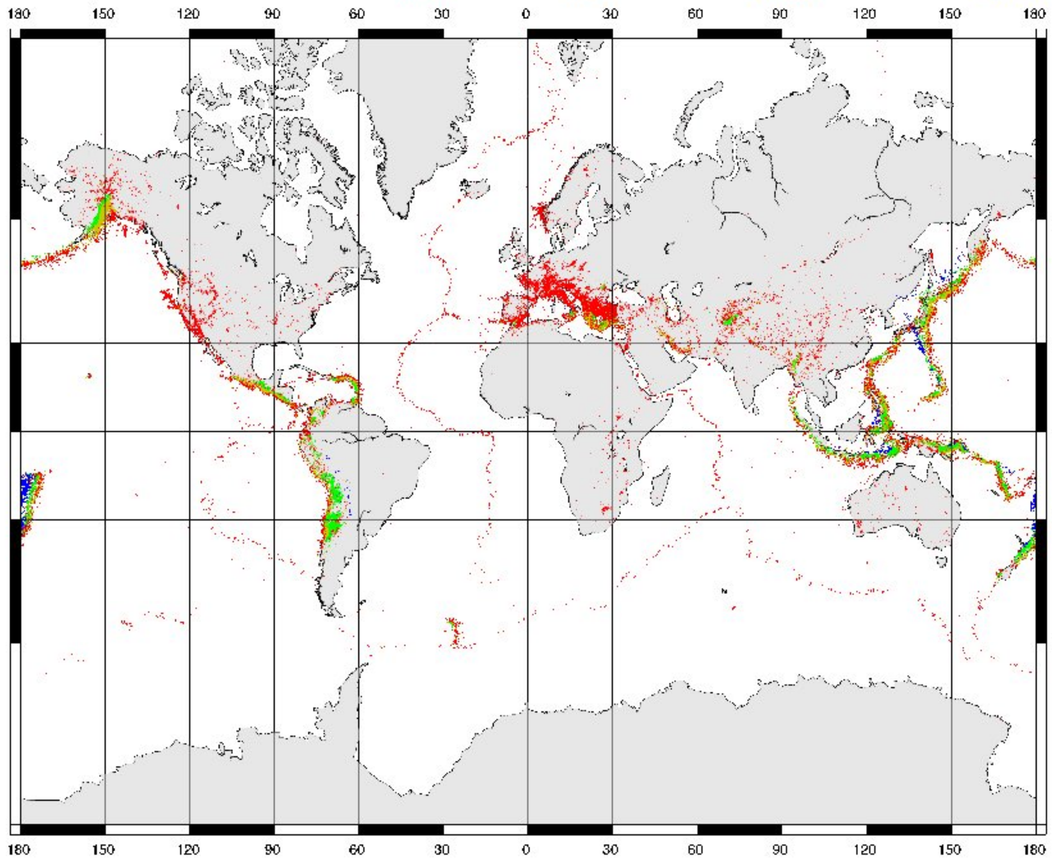
A. แผนที่แสดงแผ่นเปลือกโลก



Reference: http://www.geophys.cs.rice.edu/plateboundary/downloads.html
Edited by Rakkapao, S. (?/04/2009)

B. แผนที่แสดงตำแหน่งศูนย์เกิดแผ่นดินไหว

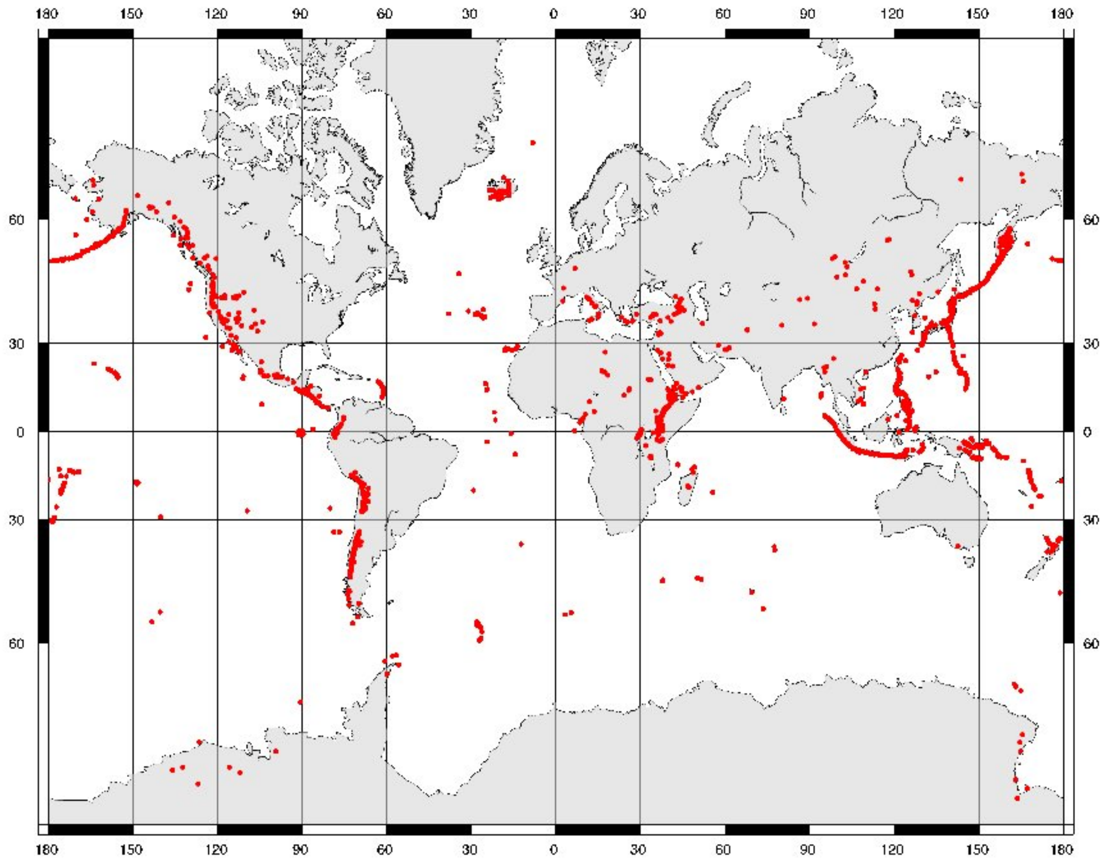
แผนที่แสดงตำแหน่งศูนย์เกิดแผ่นดินไหวทั่วโลก ข้อมูลระหว่างปี พ.ศ. 2533-2539 สำหรับแผ่นดินไหวขนาดตั้งแต่ 4 ริกเตอร์ขึ้นไป
สีของจุดบอกความลึกของศูนย์เกิดแผ่นดินไหวเทียบจากผิวโลก สีแดง = 0–33 กม. สีส้ม = 33.1–70 กม. สีเขียว = 70.1–300 กม. สีน้ำเงิน = 300.1–700 กม.



Reference: http://www.geophysics.rice.edu/plateboundary/downloads.html
Edited by Rakkapao, S.(__/04/2009)

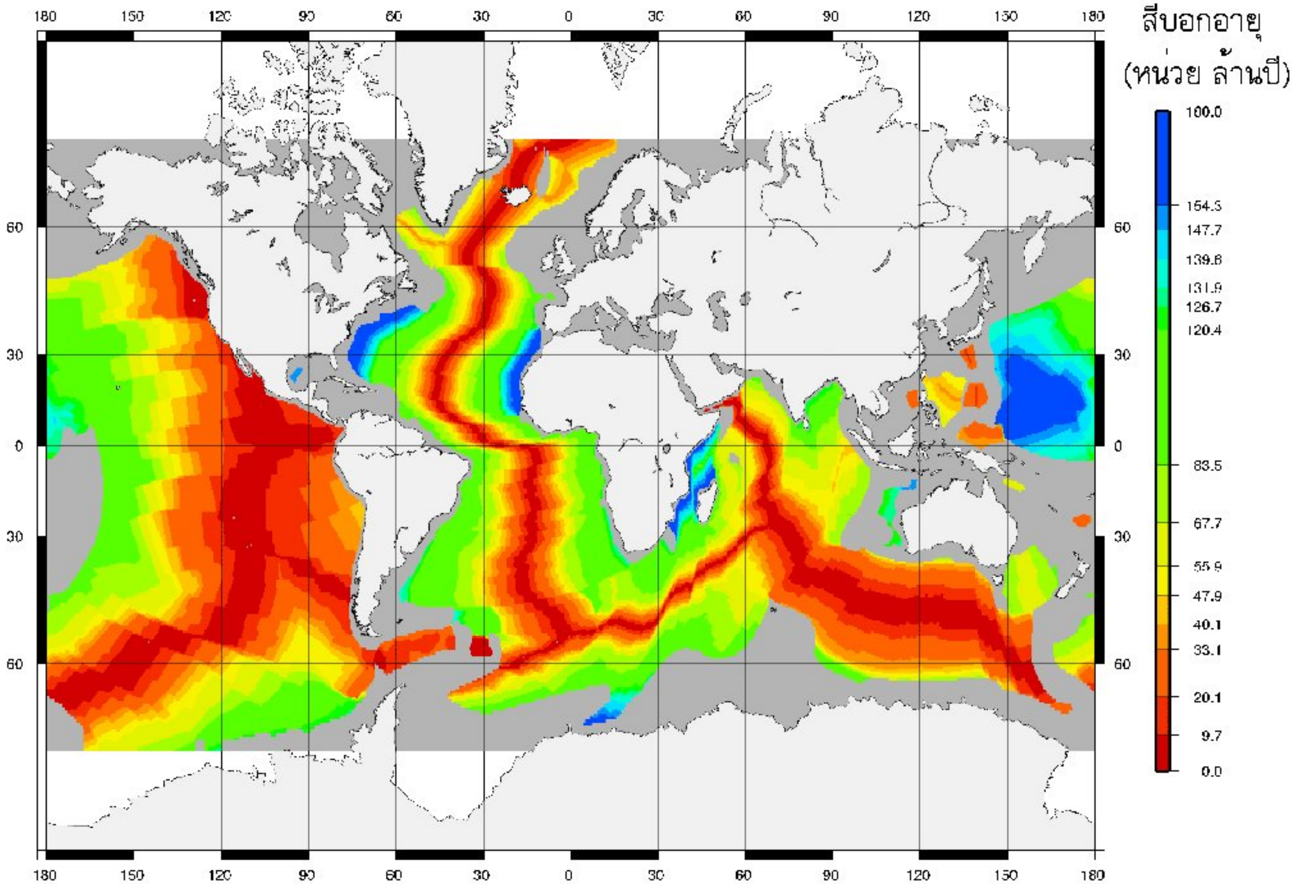
C. แผนที่แสดงตำแหน่งภูเขาไฟ

จุดสีแดง บอกตำแหน่งภูเขาไฟมีพลัง (ภูเขาไฟที่เคยปะทุแล้วในอดีตหรือมีแนวโน้มจะปะทุ)

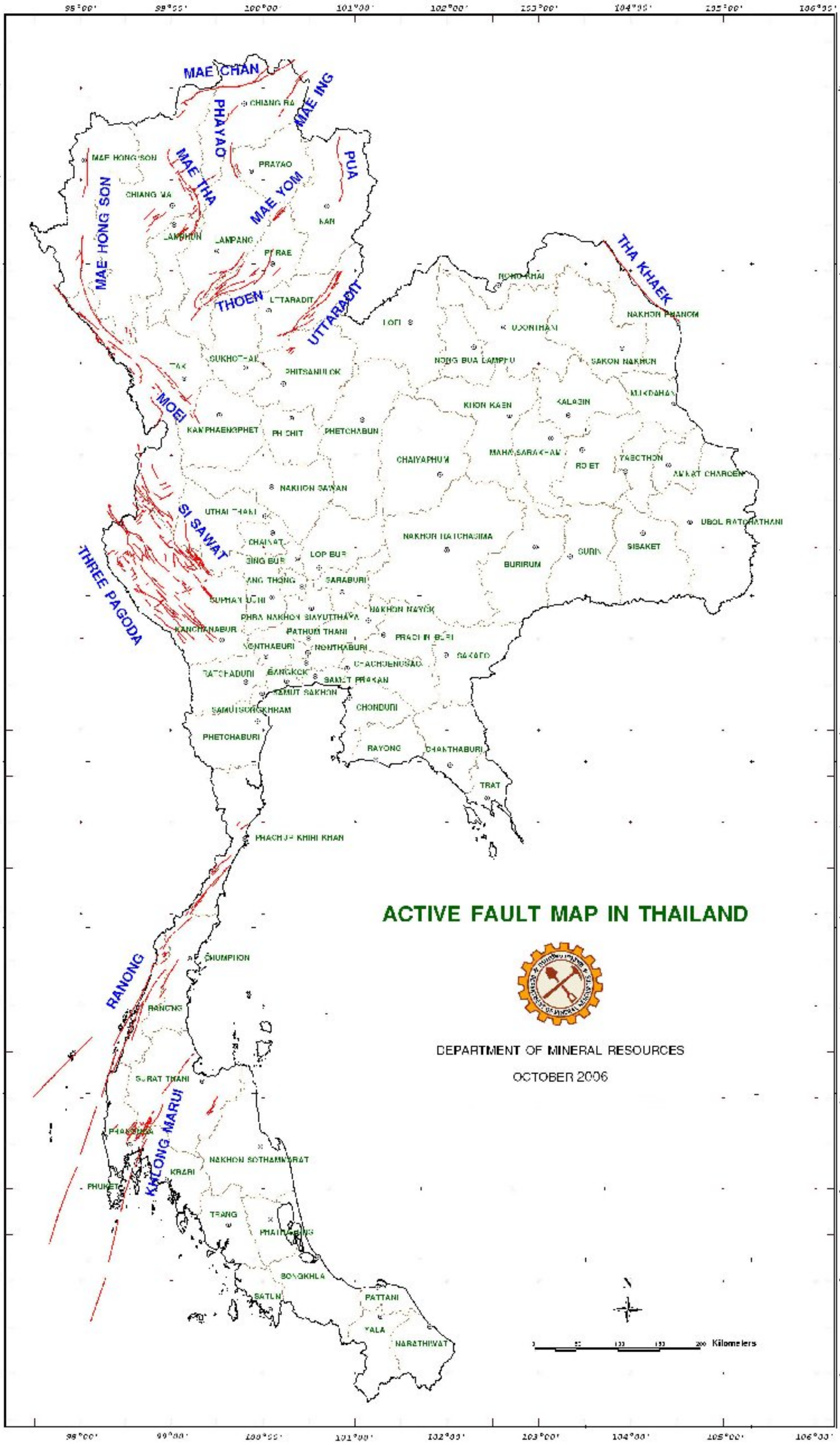


Reference: http://www.geophysics.rice.edu/plateboundary/downloads.html
Edited by Rakkapao, S. (__/04/2009)

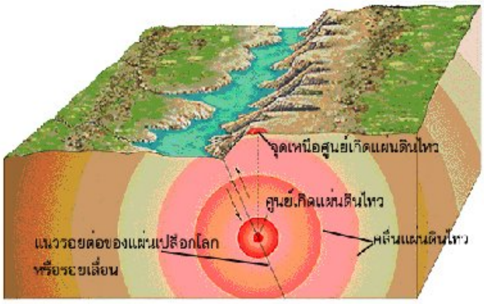
D. แผนที่แสดงอายุหินบริเวณพื้นท้องทะเล



Reference: http://www.geophysics.rice.edu/plateboundary/downloads.html
Edited by Rakkapao, S.(11/04/2009)


ACTIVE FAULT MAP IN THAILAND
DEPARTMENT OF MINERAL RESOURCES
OCTOBER 2006
MAE CHAN
MAE ING
PHAYAO
PUA
MAE THA
MAE YOM
MAE HONG SON
THOEN
UTTARADIT
THA KHAEK
MOEI
SI SAWAT
THREE PAGODA
RANONG
KHLONG MARUI
Kilometers

ใบความรู้ที่ 2 เรื่อง แนวแผ่นดินไหวส่วนใหญ่ของโลกและในประเทศไทย



เมื่อเกิดแผ่นดินไหวขึ้น ตำแหน่งเริ่มต้นที่เป็นจุดปล่อยพลังงานออกมา ซึ่งอยู่ภายใต้โลก เรียกว่า **ศูนย์เกิดแผ่นดินไหว (Focus or Hypocenter)** สำหรับตำแหน่งสมมุติที่อยู่บนผิวโลกซึ่งอยู่เหนือศูนย์เกิดแผ่นดินไหว เรียกว่า **จุดเหนือศูนย์เกิดแผ่นดินไหว (Epicenter)** โดยพลังงานที่ปล่อยออกมาในรูปคลื่นเรียกว่า **คลื่นไหวสะเทือน หรือคลื่นแผ่นดินไหว (Seismic Waves)** (รูปที่ 2.1)

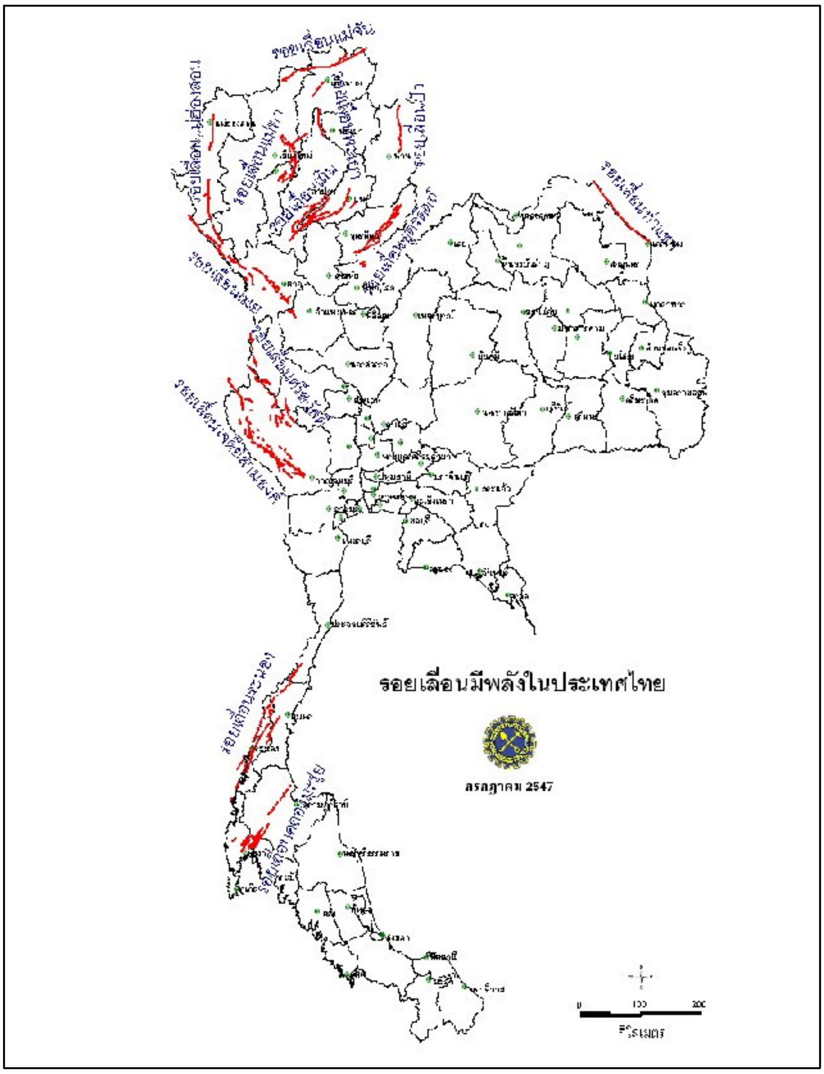
อ้างอิง: http://earthquakesandplates.wordpress.com/2008/05/12/
difference-between-earthquake-focus-and-the-epicenter/

รูปที่ 2.1 ศูนย์เกิดแผ่นดินไหว (Focus or Hypocenter) และจุดเหนือศูนย์เกิดแผ่นดินไหว (Epicenter)

จากข้อมูลเกี่ยวกับแผ่นดินไหวรวมถึงภูเขาไฟระเบิด นักวิทยาศาสตร์พบว่าตำแหน่งศูนย์เกิดแผ่นดินไหวและภูเขาไฟส่วนใหญ่อยู่ตรงแนวรอยต่อของแผ่นเปลือกโลกชนิดเคลื่อนที่เข้าหากัน แนวรอยต่อที่สำคัญที่ทำให้เกิดแผ่นดินไหวคือ แนวรอยต่อล้อมรอบมหาสมุทรแปซิฟิก โดยบริเวณนี้มีแผ่นดินไหวเป็นจำนวนมากถึง 90% ของแผ่นดินไหวทั้งหมดทั่วโลก และบริเวณนี้มักถูกเรียกว่า **แนววงแหวนแห่งไฟ (Ring of Fire)** (รูปที่ 2.2) ได้แก่ ประเทศญี่ปุ่น ฟิลิปปินส์ รวมถึงบางส่วนของสหรัฐอเมริกา แม็กซิโก และชิลี แผ่นดินไหวเหล่านี้เป็นผลโดยตรงมาจากการเคลื่อนตัวของแผ่นเปลือกโลก เช่น แผ่นเปลือกโลกนาซกา (Nazca Plate) และแผ่นเปลือกโลกโคโคส์ (Cocos Plate) กำลังเคลื่อนตัวและมุดลงใต้แผ่นเปลือกโลกอเมริกันใต้ (South American Plate) แผ่นเปลือกโลกจูเดอ ฟูกา กำลังมุดตัวลงใต้แผ่นเปลือกโลกอเมริกันเหนือ (North American Plate) และแผ่นเปลือกโลกอินโด-ออสเตรเลียน (Indo-Australian Plate) มุดตัวลงใต้แผ่นเปลือกโลกยูเรเซียน (Eurasian plate)

(อ้างอิง: http://www.enchantedlearning.com/subjects/volcano/ringoffire/)

รูปที่ 2.2 แนววงแหวนแห่งไฟ (Ring of Fire)



(อ้างอิง: http://www.dmr.go.th/knowledge/geology.htm)

รูปที่ 2.3 รอยเลื่อนที่สำคัญในประเทศไทย

สำหรับประเทศไทย เนื่องจาก**<u>ไม่ได้ตั้งอยู่ตรงรอยต่อของแผ่นเปลือกโลก</u>** จึงจัดได้ว่าเป็นพื้นที่เสี่ยงภัยแผ่นดินไหวระดับต่ำถึงปานกลาง ทั้งนี้เพราะประเทศไทยยังมีรอยเลื่อนที่มีพลัง (Active Fault) อยู่จำนวนหนึ่ง เช่น รอยเลื่อนเชียงแสน รอยเลื่อนแม่ทา รอยเลื่อนเถิน รอยเลื่อนศรีสวัสดิ์ รอยเลื่อนเจดีย์สามองค์ รอยเลื่อนระนอง และรอยเลื่อนคลองมะรุ่ย (รูปที่ 2.3) (สำหรับความหมายของ "รอยเลื่อนที่มีพลัง" นั้น ในอเมริกาเชื่อว่าเป็นรอยแตก หรือรอยแยกของแผ่นเปลือกโลกที่เคยเป็นศูนย์เกิดแผ่นดินไหวขนาดมากกว่า 6 ริกเตอร์ ในช่วงของยุคควอเทอร์นารี (Quaternary) หรือประมาณ 1.8 ล้านปีมาแล้ว) อีกทั้งอาจได้รับแรงสั่นสะเทือนแผ่นดินไหวจากประเทศเพื่อนบ้าน เช่น บริเวณตอนใต้ของจีน พม่า ลาว รวมถึงอาจได้รับผลจากแผ่นดินไหว เช่น คลื่นซึนามิ (Tsunami) ถ้าเกิดแผ่นดินไหวขนาดใหญ่บริเวณทะเลอันดามันและตอนเหนือของเกาะสุมาตรา เป็นต้น โดยพื้นที่ที่มีความเสี่ยงจากการเกิดแผ่นดินไหวมากที่สุดในประเทศไทย ได้แก่ จังหวัดเชียงราย แม่ฮ่องสอน และตาก

Lesson Plan 3: Seismic Waves

3.1 Objectives

(1) Students are able to discuss the longitudinal and transverse waves.

(2) Students are able to discuss the seismic waves (P-waves, S-waves, and surface waves).

(3) Students are able to discuss the seismic wave properties that its speed depends on the density and elasticity of the medium; not depends on the magnitude and frequency of the waves.

3.2 Times 50 minutes

3.3 Teaching Tools

(1) Slinky

(2) String

(3) Red ribbon

(4) Animation pictures of seismic waves

(5) Worksheet 2: Seismic Waves

(6) Summary document 3: Seismic Waves

(7) Lecture power point

3.4 Teaching Processes

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 1: Engagement	5	(1) The teacher briefly summarizes the concept of earthquake region in the World, from the last period again. (2) Students share their understanding of longitudinal and transverse waves with other friends.
Step 2: Exploration	25	(3) Students demonstrate the longitudinal waves by using the slinky tied with the red ribbon, and note in the worksheet.

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
		(4) Again, students demonstrate the transverse waves by using the string tied with the red ribbon, and note in the worksheet.
Step 3: Explanation	10	(5) Students discuss the waves and look at the animations of seismic waves. (6) Students discuss the seismic waves and note in the worksheet.
Step 4: Elaboration	5	(7) Students play the human seismic waves.
Step 5: Evaluation	5	(8) Students answer questions in worksheet.

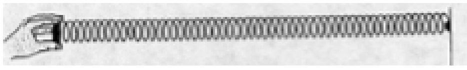
Slinky for the longitudinal wave demonstration

String for the transverse wave demonstration

ชื่อ....................................นามสกุล......................
ชั้น..................เลขที่........................

ใบงานที่ 2 เรื่อง คลื่นตามยาวและคลื่นตามขวาง

<u>**การสาธิตที่ 1**</u> ออกแรงดันสปริง***เข้า-ออก*** บนพื้นราบ
ให้นักเรียน**วาดรูปสปริง**ที่สังเกตเห็น

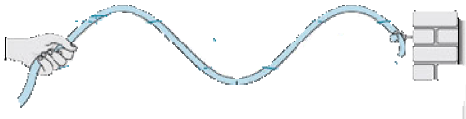


<u>**กำหนดให้**</u>ตำแหน่งที่ผูกริบบิ้นแดงแทนอนุภาคสปริงที่กำลังพิจารณาและเขียนแทนด้วยจุดกลม (●)
ให้นักเรียน**วาดลูกศร**แสดงทิศการเคลื่อนที่ของริบบิ้นแดงเมื่อออกแรงกระทำสปริง พร้อมทั้ง**ระบุทิศการเคลื่อนที่ของคลื่น**

●

อนุภาคสปริง

<u>**การสาธิตที่ 2**</u> ออกแรงสะบัดเชือก***ขึ้น-ลง*** ในแนวดิ่ง
ให้นักเรียน**วาดรูปเชือก**ที่สังเกตเห็น



<u>**กำหนดให้**</u> ตำแหน่งที่ผูกริบบิ้นแดงแทนอนุภาคเชือกที่กำลังพิจารณาและเขียนแทนด้วยจุดกลม (●)
ให้นักเรียน**วาดลูกศร**แสดงทิศการเคลื่อนที่ของริบบิ้นแดงเมื่อออกแรงกระทำเชือก พร้อมทั้ง**ระบุทิศการเคลื่อนที่ของคลื่น**

●

อนุภาคเชือก

มาสรุปกันหน่อยนะ 

1. **คลื่นตามยาว** หมายถึง..

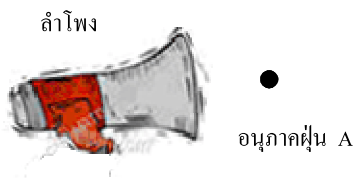
ตัวอย่าง คลื่นตามยาว ได้แก่..

2. **คลื่นตามขวาง** หมายถึง..

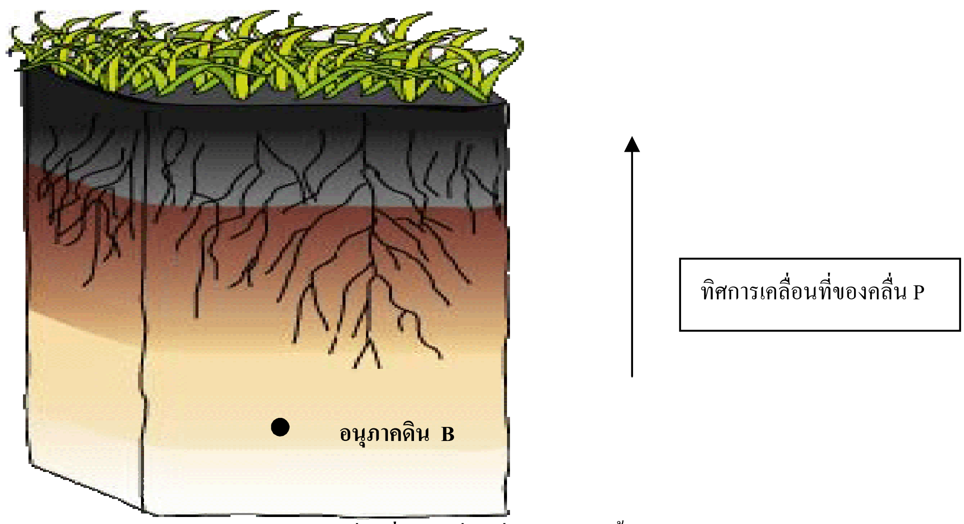
ตัวอย่าง คลื่นตามขวางได้แก่..

ให้นักเรียนตอบคำถามต่อไปนี้

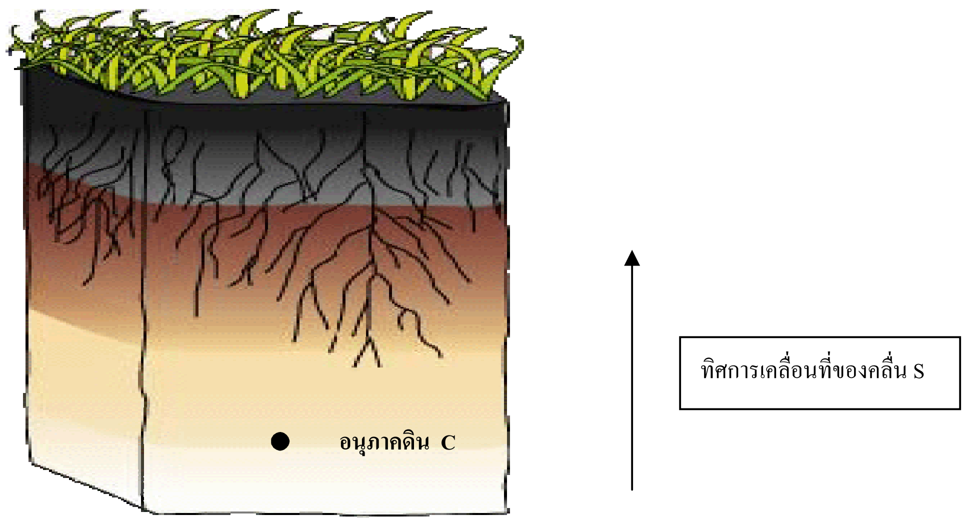
1. อนุภาคฝุ่น A (เขียนแทนด้วยจุดกลม ●) ลอยอยู่หน้าลำโพงดังรูป เมื่อเปิดลำโพง ให้นักเรียน**<u>วาดลูกศร</u>**แสดงทิศการเคลื่อนที่ของอนุภาคฝุ่น A ลงบนจุดกลม



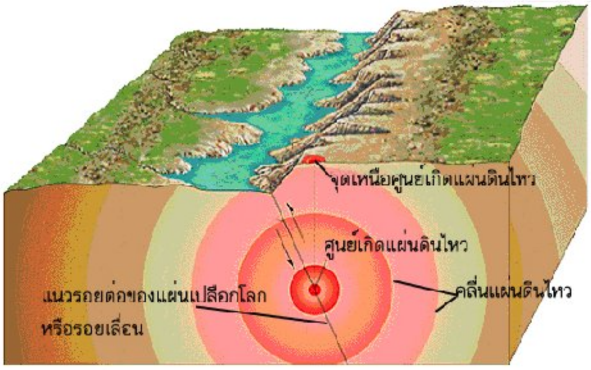
2. อนุภาคดิน B (เขียนแทนด้วยจุดกลม ●) วางตัวอยู่ดังรูป เมื่อ**<u>คลื่น P</u>** เคลื่อนที่ผ่านจากล่างขึ้นบน(ตามทิศของลูกศร) ให้นักเรียน**<u>วาดลูกศร</u>**แสดงทิศการเคลื่อนที่ของอนุภาคดิน B ลงบนจุดกลม



3. อนุภาคดิน C (เขียนแทนด้วยจุดกลม ●) วางตัวอยู่ดังรูป เมื่อ**<u>คลื่น S</u>** เคลื่อนที่ผ่านจากล่างขึ้นบน (ตามทิศของลูกศร) ให้นักเรียนวาดลูกศรแสดงทิศการเคลื่อนที่ของอนุภาคดิน C ลงบนจุดกลม



ใบความรู้ที่ 3 เรื่อง คลื่นแผ่นดินไหว

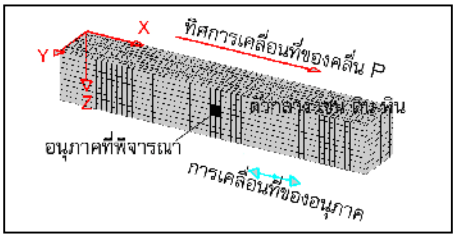


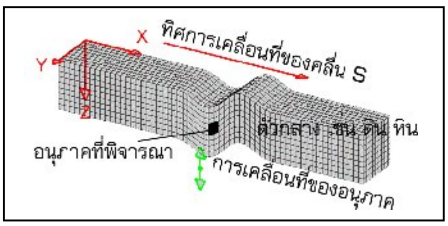
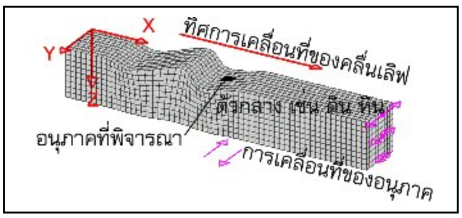
อ้างอิงรูปภาพ: http://earthquakesandplates.wordpress.com/2008/05/12/difference-between-earthquake-focus-and-the-epicenter/

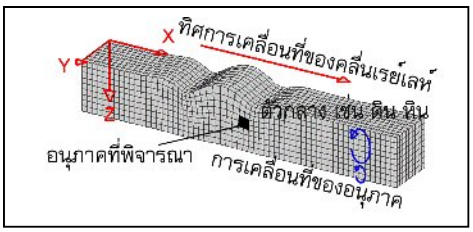
การเคลื่อนที่ของแผ่นเปลือกโลกซึ่งมีสาเหตุมาจากการหมุนเวียนของความร้อนและสสารภายใต้โลกทำให้เกิดแผ่นดินไหว โดยพลังงานที่ถูกปลดปล่อยออกมาในรูปคลื่น เราเรียกว่า **คลื่นไหวสะเทือน หรือคลื่นแผ่นดินไหว (Seismic Waves)** ซึ่งคลื่นแผ่นดินไหวนี้จะเดินทางจากศูนย์เกิดแผ่นดินไหวหนึ่งๆ ผ่านชั้นหิน ดินไปยังส่วนต่างๆได้ทั่วโลก (รูปที่ 3.1)

รูปที่ 3.1 คลื่นแผ่นดินไหวเริ่มแผ่จากศูนย์เกิดแผ่นดินไหวไปยังส่วนต่างๆ ทั่วโลก

คลื่นแผ่นดินไหวมีคุณสมบัติขึ้นอยู่กับความยืดหยุ่นของตัวกลาง ได้แก่ ความหนาแน่น และ ค่าคงตัวการยืดหยุ่น คลื่นแผ่นดินไหวแบ่งออกเป็น 2 แบบหลักๆ ตามบริเวณที่มันเคลื่อนที่ผ่าน ดังนี้คือ

<table>
<tr><td colspan="2">1. คลื่นภายในตัวกลาง (Body Waves)
เป็นคลื่นแผ่นดินไหวที่เคลื่อนที่ภายในโลก แบ่งออกเป็น 2 ชนิด ตามลักษณะการเคลื่อนที่ของอนุภาคตัวกลางเมื่อคลื่นเคลื่อนที่ผ่าน</td><td colspan="2">2. คลื่นพื้นผิว (Surface Waves)
เป็นคลื่นแผ่นดินไหวที่เคลื่อนที่ที่ผิวโลก แม้คลื่นกลุ่มนี้จะเดินทางได้ช้ากว่าคลื่น P และคลื่น S แต่มันสร้างความเสียหายให้ได้มากกว่า แบ่งย่อยออกเป็น 2 ชนิด</td></tr>
<tr><td>1.1คลื่นปฐมภูมิ (Primary Waves) หรือ คลื่น P</td><td>1.2 คลื่นทุติยภูมิ (Secondary Waves) หรือ คลื่น S</td><td>2.1 คลื่นเลิฟ (Love waves)</td><td>2.2 คลื่นเรย์เลห์ (Rayleigh Waves)</td></tr>
<tr><td>เป็นคลื่นตามยาว คืออนุภาคตัวกลางจะเคลื่อนที่อัดและขยายในทิศเดียวกับทิศการเคลื่อนที่ของคลื่น คลื่นนี้เดินทางได้เร็วกว่าคลื่นแผ่นดินไหวทุกชนิด</td><td>เป็นคลื่นตามขวาง คืออนุภาคตัวกลางจะเคลื่อนที่ตั้งฉากกับทิศการเคลื่อนที่ของคลื่น</td><td>เป็นคลื่นตามขวาง คล้ายคลื่น S แต่อนุภาคตัวกลางจะเคลื่อนที่ตั้งฉากในระนาบเดียวกับทิศการเคลื่อนที่ของคลื่น</td><td>เป็นคลื่นที่ทำให้อนุภาคตัวกลางเคลื่อนที่เป็นวงรีเมื่อคลื่นเคลื่อนที่ผ่าน โดยวงรีจะมีขนาดเล็กลงตามความลึก</td></tr>
<tr><td colspan="2">


</td><td colspan="2">


</td></tr>
</table>

Lesson Plan 4: The Principle of Seismographs

4.1 Objectives

(1) Students are able to discuss the mechanical principle of seismograph.

(2) Students are able to interpret the basic ideas of seismogram.

4.2 Times 50 minutes

4.3 Teaching Tools

(1) A simple seismograph

(2) Online seismograms

(3) Worksheet 3: Principle of Seismograph

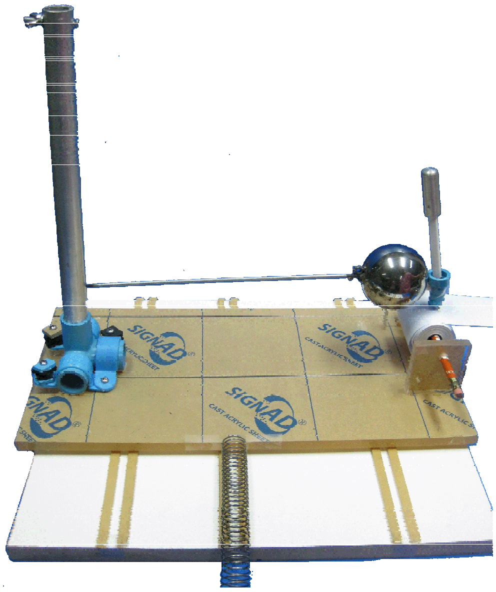
(4) Summary document 4: Principle of Seismograph

(5) Lecture power point

4.4 Teaching Processes

The 5-E model of the inquiry-based learning method	**Times (minutes)**	**Activities**
Step 1: Engagement	10	(1) The teacher briefly summarizes the concept of seismic waves, from the last period again. (2) Students discuss the picture involving the attaching ear to ground about what and why. (3) The teacher and students discuss the history of the first seismoscope.
Step 2: Exploration	25	(4) Students do experiment by using the simple seismograph. (5) Students discuss the principle of seismograph, and answer the questions in the worksheet.
Step 3: Explanation	5	(6) The teacher and students discuss the seismometers in Thailand.
Step 4: Elaboration	5	(7) Students study the interpretation of the basic ideas of seismogram.

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 5: Evaluation	5	(8) Students answer questions in the worksheet.



The Simple Seismograph Constructed by the Researchers

Applications for Instruction

1. Use the simple seismograph with the worksheet step by step.
2. Shake the base frame of the seismograph to record the artificial quake signal on the paper rotated by a student. Study the mechanical principle of the instrument, including its components and properties.
3. Study about the anatomy of a wave diagram (amplitude, a wave length, a frequency, a period, a crest, and a trough) by using the seismogram.
4. Learn about the P-waves, S-waves and surface waves.
5. By small and large shaking, study about the relation between earthquake magnitudes and amplitudes of wave diagrams on seismograms.
6. Shake the base frame by the spring to learn about the relation between the medium's motions at P-wave (longitudinal wave) arrival, and the recording signals on the seismogram.

ชื่อ..นามสกุล............................

ชั้น.....................เลขที่......................

ใบงานที่ 3 เรื่อง หลักการของเครื่องมือวัดแผ่นดินไหว

1. เครื่องมือวัดแผ่นดินไหวประกอบด้วยส่วนประกอบที่สำคัญอะไรบ้าง

1)
2)
3)
4)
5)

2. จากชุดสาธิต **ภาพใดแสดงแผ่นดินไหวขนาดใหญ่กว่ากัน** เพราะเหตุใด

A

B

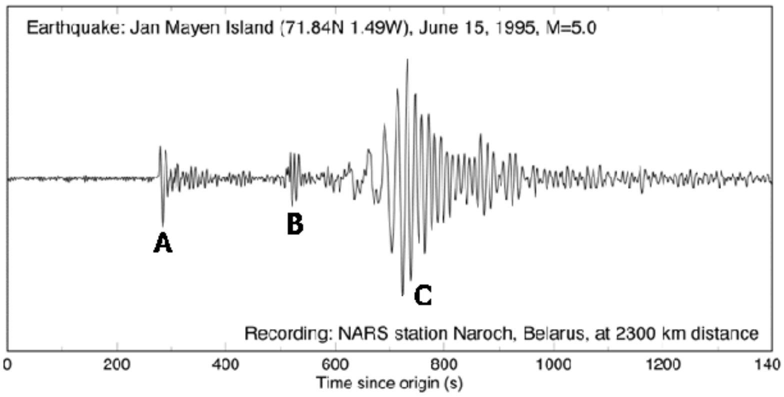
ภาพกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว

คำตอบ

3. จากชุดสาธิต ถ้าเปลี่ยนจากลูกตุ้มที่หนักมาเป็นลูกตุ้มเบาที่ทำจากโฟม สิ่งที่บันทึกได้บนกระดาษจะมีลักษณะอย่างไร

ทำนาย	**คำตอบ**

4. เครื่องมือวัดแผ่นดินไหวมีหลักการทำงานอย่างไร



5. จากตัวอย่างกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว(ด้านบน) ตำแหน่ง A, B และ C บนกระดาษ หมายถึงสัญญาณคลื่นแผ่นดินไหวชนิดใด

ตำแหน่ง A คือ
ตำแหน่ง B คือ
ตำแหน่ง C คือ

6. คลื่นแผ่นดินไหวที่บันทึกได้ที่ตำแหน่ง **A B C** ของตัวอย่างกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหวด้านบน จัดเป็น**คลื่นตามยาว**

7. คลื่นแผ่นดินไหวที่บันทึกได้ที่ตำแหน่ง **A B C** ของตัวอย่างกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหวด้านบน จัดเป็น**คลื่นตามขวาง**

8. คลื่นแผ่นดินไหวที่เคลื่อนที่ผ่านชั้นดินและหินด้วยอัตราเร็วสูงกว่าคลื่นแผ่นดินไหวชนิดอื่น คือ

9. คลื่นแผ่นดินไหวที่ทำให้เกิดความเสียหายต่อมนุษย์และอาคารสิ่งปลูกสร้างมากที่สุด คือ

10. ให้นักเรียน**วาดรูปคลื่น**ที่บันทึกได้ในกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว เมื่อ**คลื่นตามยาว**เคลื่อนที่มาถึงเครื่องมือวัดแผ่นดินไหวชนิดวัดการสั่นของอนุภาคในแนวราบ (แบบชุดสาธิต)

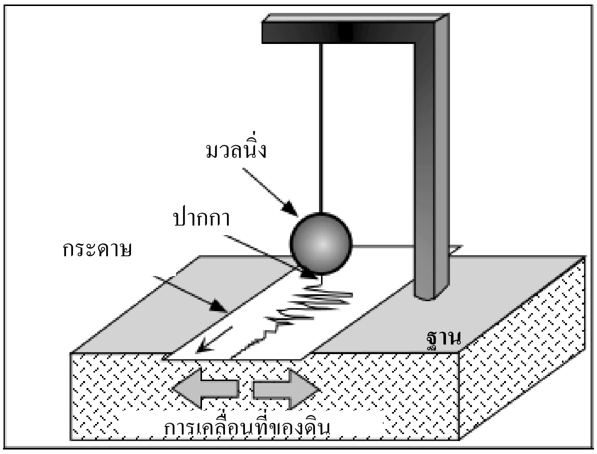
11. ให้นักเรียน**วาดรูปคลื่น**ที่บันทึกได้ในกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว เมื่อ**คลื่นตามขวาง**เคลื่อนที่มาถึงเครื่องมือวัดแผ่นดินไหวชนิดวัดการสั่นของอนุภาคในแนวราบ (แบบชุดสาธิต)

ใบความรู้ที่ 4 เรื่อง หลักการของเครื่องมือวัดแผ่นดินไหว

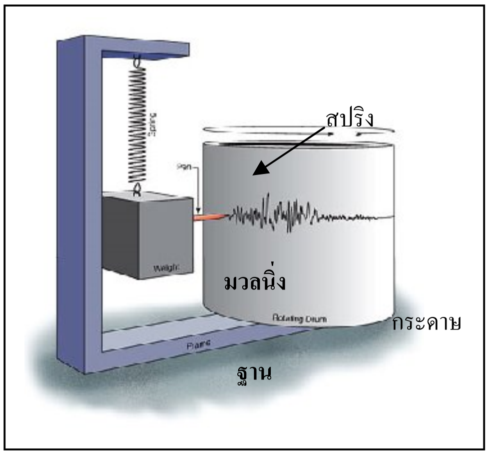
เครื่องวัดแผ่นดินไหว (Seismometer) เป็นเครื่องมือสำหรับวัดการสั่นสะเทือนของพื้นดิน โดยมีหลักการวัดหลักๆ 2 แบบ คือ 1) วัดการเคลื่อนที่ของพื้นดินเทียบกับมวลนิ่ง หรือเรียกว่า เครื่องวัดแผ่นดินไหวแบบมวลเฉื่อย (Inertial Seismometers) และ 2) วัดการเคลื่อนที่ของพื้นดินที่จุดหนึ่งเทียบกับจุดอื่น หรือเรียกว่าเครื่องวัดแผ่นดินไหวแบบคาบยาว (Extensometers) ซึ่งมักใช้สำหรับคลื่นไหวสะเทือนที่มีคาบยาวมากๆ

สำหรับเครื่องวัดแผ่นดินไหวแบบมวลเฉื่อย มีโครงสร้าง 2 แบบ คือ โครงสร้างสำหรับวัดการสั่นของอนุภาคตัวกลางในแนวนอน และในแนวตั้ง (รูปที่ 4.1) ทั้ง 2 แบบมีส่วนประกอบหลักที่เหมือนกันดังนี้

1. ลูกตุ้มที่หนักมาก (หรือมวลเฉื่อย) ผูกติดกับเชือกหรือสปริงและห้อยอยู่กับโครง โดยปลายด้านหนึ่งของลูกตุ้มมีปากกาติดอยู่ ทำหน้าที่เป็นมวลนิ่ง
2. ส่วนบันทึกสัญญาณคลื่นไหวสะเทือน เช่น **กระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว (Seismogram)** หรือ โปรแกรมคอมพิวเตอร์ สำหรับกระดาษนั้นจะติดอยู่ที่โครงซึ่งตรึงอยู่ที่พื้นดิน และจะหมุนได้เพื่อป้องกันไม่ให้บันทึกสัญญาณคลื่นซ้ำตำแหน่งเดิม
3. ส่วนบันทึกเวลาที่เครื่องมือนี้ตรวจพบคลื่นไหวสะเทือน



(A)

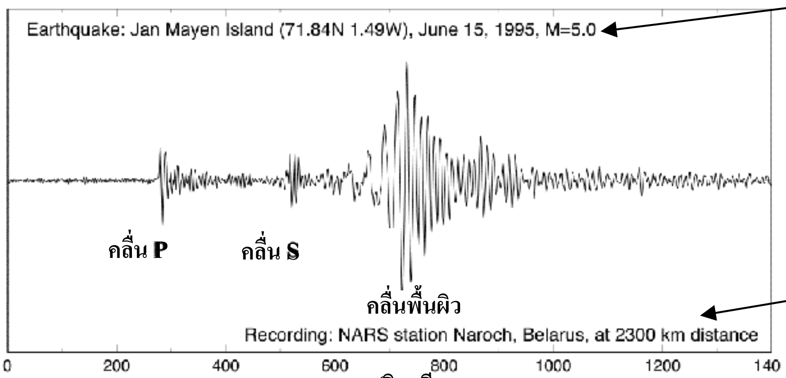


(B)

รูปที่ 4.1 เครื่องวัดแผ่นดินไหวที่วัดการสั่นของอนุภาคตัวกลางในแนวนอน (A) และแนวตั้ง (B)

(อ้างอิง: http://earthsci.org/education/teacher/basicgeol/earthq/seismograph.gif)

หลักการทำงานของเครื่องวัดแผ่นดินไหวโดยทั่วไปคือ เมื่อคลื่นแผ่นดินไหวเดินทางมาถึงบริเวณที่ติดตั้งเครื่องวัด มันจะทำให้อนุภาคดินหรือหินบริเวณฐานของเครื่องมือสั่นไปด้วย สำหรับส่วนที่เป็นมวลเฉื่อยจะเคลื่อนที่ได้ยากและส่วนนี้มีปากกาติดอยู่ การเคลื่อนที่ของกระดาษ(ที่ติดอยู่ที่ฐานซึ่งตรึงอยู่กับพื้น) ทำให้ปากกาขีดลงบนกระดาษได้ การเคลื่อนที่สัมพัทธ์กันของกระดาษบันทึกกับปากกานี้เป็นการบันทึกลักษณะการสั่นของอนุภาคตัวกลางหรือสัญญาณคลื่นแผ่นดินไหวนั่นเอง



รูปที่ 4.2 ตัวอย่างกระดาษบันทึกสัญญาณคลื่นไหวสะเทือน

(อ้างอิง: http://chuma.cas.usf.edu/~juster/A3/seismogram.gif)

Lesson Plan 5: Locating the Epicenter

5.1 Objectives

Students are able to locate the epicenter of an earthquake from the seismograms

5.2 Times 50 minutes

5.3 Teaching Tools

(1) Online seismograms

(2) P-S curve graph

(3) Dividers and protractors

(4) Worksheet 4: Locate the Epicenter

(5) Summary document 5: Locate the Epicenter

(6) Lecture power point

5.4 Teaching Processes

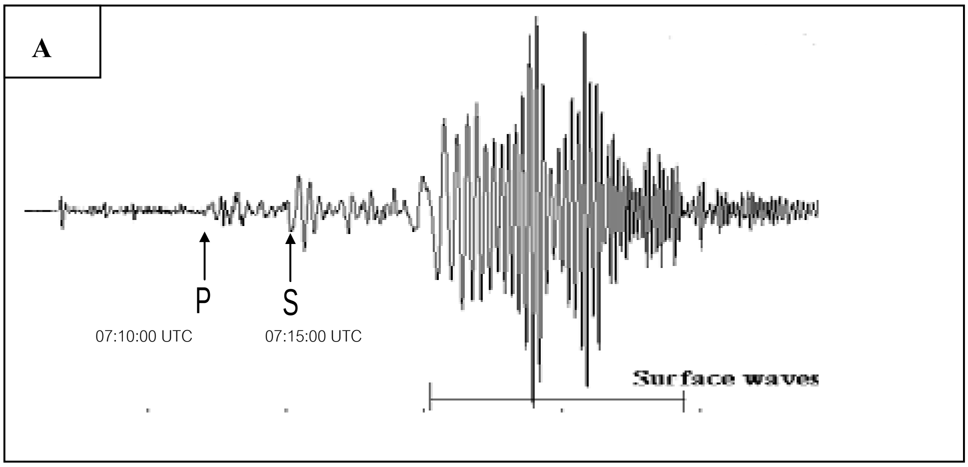
The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
Step 1: Engagement	10	(1) The teacher briefly summarizes the concept of the principle of seismograph, from the last period again. (2) Students play game to find the treasure trove. (3) Students discuss the way to find out.
Step 2: Exploration	25	(4) Students interpret the 3 seismograms. (5) Students locate the epicenter by using 3 seismograms.
Step 3: Explanation	5	(6) Students discuss the way to locate the epicenter.
Step 4: Elaboration	5	(7) The teacher and students discuss the GPS system and Doppler effect.
Step 5: Evaluation	5	(8) Students conclude their own ideas about the locating the epicenter.

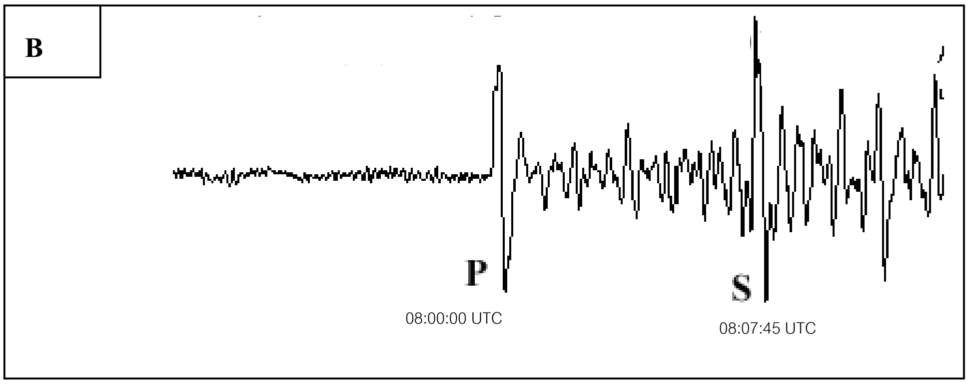
ชื่อ..นามสกุล............................
ชั้น.....................เลขที่......................

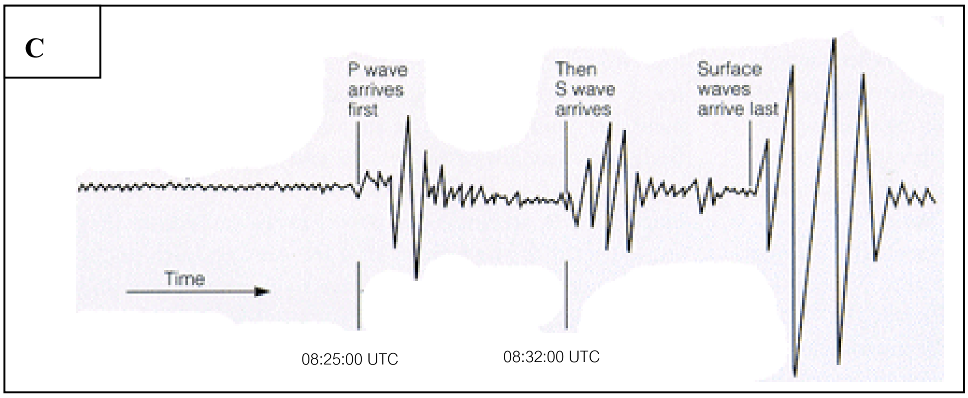
ใบงานที่ 4 เรื่อง การหาจุดเหนือศูนย์เกิดแผ่นดินไหว

ให้นักเรียนคำนวณหาตำแหน่งจุดเหนือศูนย์เกิดแผ่นดินไหว โดยอาศัยข้อมูลเหล่านี้

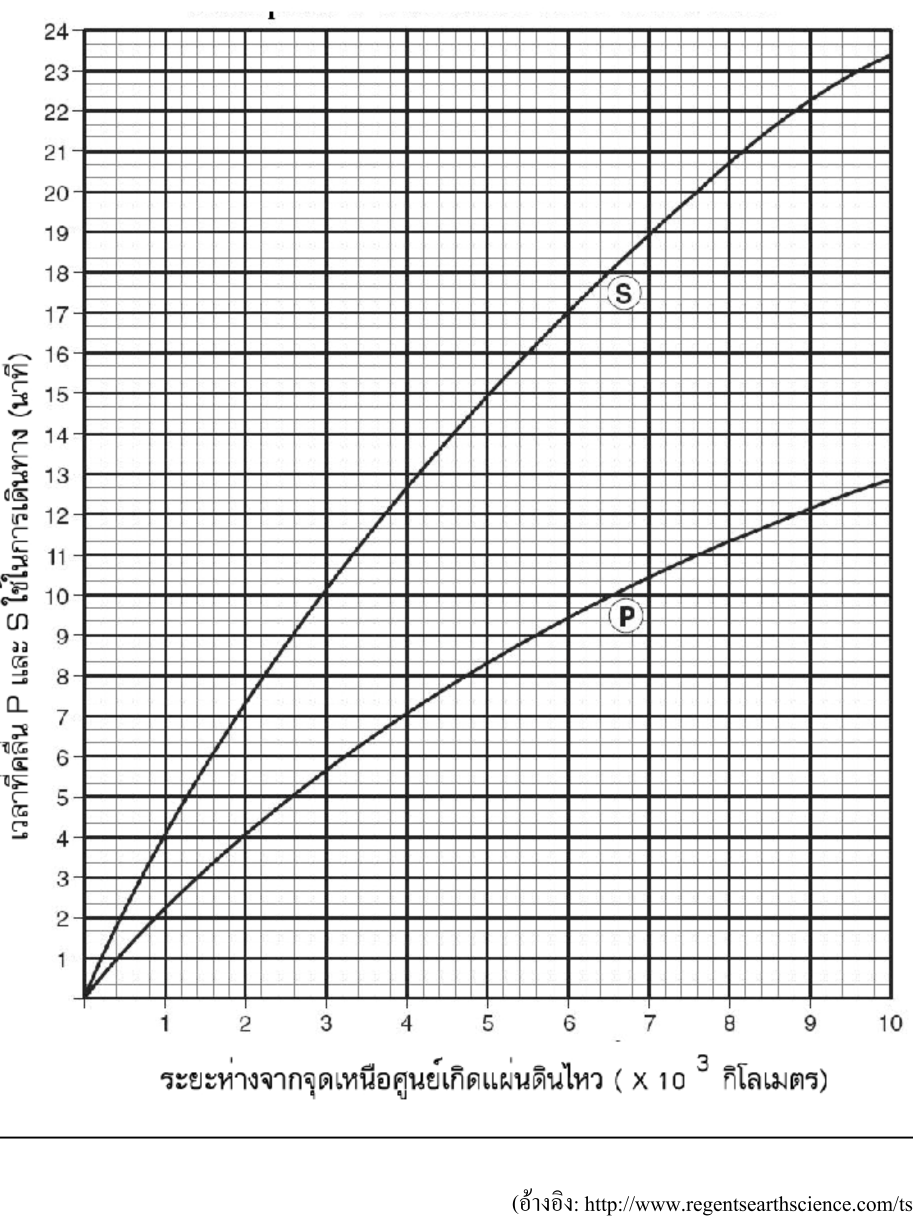
สถานการณ์: เกิดแผ่นดินไหวขึ้นที่อินโดนีเซีย สถานีตรวจวัดแผ่นดินไหวแห่งหนึ่งในกรุงจาการ์ตา ตรวจพบพบคลื่นแผ่นดินไหวและบันทึกสัญญาณคลื่นได้ดังรูป A สถานีตรวจวัดแผ่นดินไหวอีกแห่งหนึ่งซึ่งอยู่ทางทิศเหนือของกรุงจาการ์ตา ห่างออกไป 3,100 กิโลเมตร บันทึกสัญญาณคลื่นได้ดังรูป B และอีกสถานีซึ่งอยู่ทางทิศตะวันออกเฉียงเหนือของกรุงจาการ์ตา ห่างออกไป 4,700 กิโลเมตร บันทึกสัญญาณคลื่นได้ดังรูป C







กราฟแสดงความสัมพันธ์ระหว่างเวลาที่คลื่น P และ S ใช้ในการเดินทางที่ระยะทางต่างๆ กัน



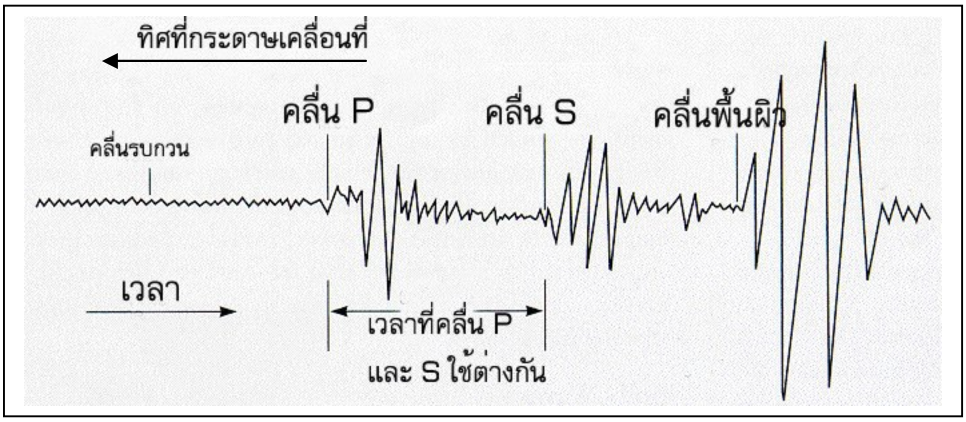
(อ้างอิง: http://www.regentsearthscience.com/tsunami.htm)

ใบความรู้ที่ 5 เรื่อง การหาตำแหน่งจุดเหนือศูนย์เกิดแผ่นดินไหว

เราสามารถคำนวณหาตำแหน่งจุดเหนือศูนย์เกิดแผ่นดินไหวได้ โดยอาศัยสมบัติเกี่ยวกับผลต่างของอัตราเร็วของคลื่น P และ S ซึ่งมีวิธีการหลักๆ ดังนี้

1) หาเวลาที่คลื่น P และคลื่น S ใช้ต่างกัน

หาเวลาที่คลื่น P และคลื่น S ใช้ต่างกันบนกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว จากอย่างน้อยจาก 3 สถานี (รูปที่ 5.1)

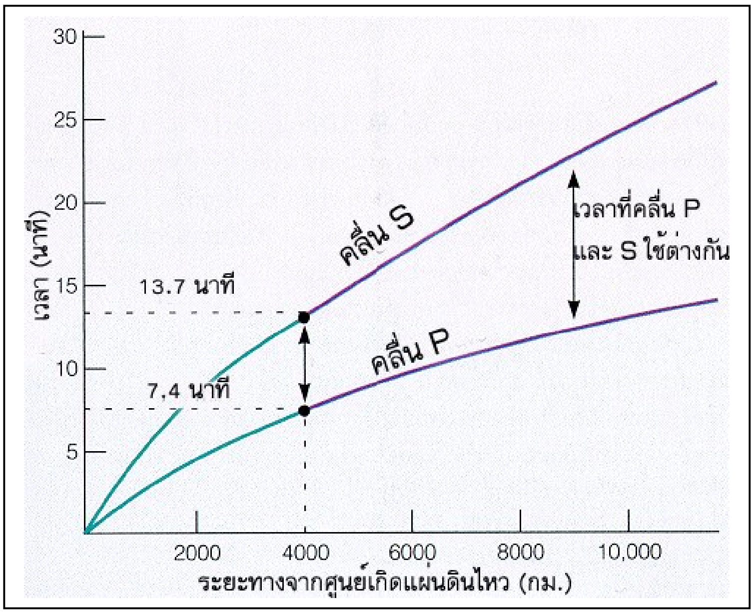


(อ้างอิง: http://ww2.lafayette.edu/~malincol/Geol120/earthquaketopics.html)

รูปที่ 5.1 ตัวอย่างกระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว

2) แปลงเวลาที่ได้เป็นระยะทาง

นำช่วงเวลาที่คลื่น P และ S ใช้ต่างกันที่ได้จากข้อ 1 ไปทาบบนกราฟ S-P (รูปที่ 5.2) เพื่อหาระยะห่างของตำแหน่งของสถานีวัดแผ่นดินไหวกับจุดเหนือศูนย์เกิดแผ่นดินไหว



(อ้างอิง: http://ww2.lafayette.edu/~malincol/Geol120/earthquaketopics.html)

รูปที่ 5.2 ตัวอย่างกราฟ S-P

3) หาจุดตัดของวงกลมทั้ง 3 วง

สร้างวงกลม 3 วงที่มีรัศมีเท่ากับค่าระยะทางที่คำนวณได้จากข้อ 2 จุดตัดของวงกลมทั้ง 3 วงนี้ เป็นตำแหน่งของจุดเหนือศูนย์เกิดแผ่นดินไหว (รูปที่ 5.3)

(อ้างอิง: http://ww2.lafayette.edu/~malincol/Geol120/earthquaketopics.html)

รูปที่ 5.3 จุดตัดของวงกลม 3 วงเป็นตำแหน่งจุดเหนือศูนย์เกิดแผ่นดินไหว

Lesson Plan 6: Magnitude and Intensity of Earthquakes

6.1 Objectives

(1) Students are able to discuss the magnitude and intensity scales of earthquakes.

(2) Students are able to discuss the relation between the amplitude and energy of a wave involving the Richter scale.

(3) Students are able to identify the difference between magnitude (the Richter scale) and intensity (the modified Mercalli scale) scale of earthquake strength.

6.2 Times 50 minutes

6.3 Teaching Tools

(1) Earthquake videos

(2) Worksheet 5: Magnitude and Intensity of Earthquakes

(3) Summary document 6: Magnitude and Intensity of Earthquakes

(4) Lecture power point

6.4 Teaching Processes

The 5-E model of the inquiry-based learning method	**Times (minutes)**	**Activities**
Step 1: Engagement	5	(1) The teacher briefly summarizes the concept of the locating the epicenter, from the last period again. (2) Students watch earthquake videos and discuss the magnitude and intensity scales of earthquake strength reported in the videos.
Step 2: Exploration	15	(3) Students perform the worksheet 5. (4) Students study to calculate the Richter scale from the graph.

The 5-E model of the inquiry-based learning method	Times (minutes)	Activities
		(5) Students discuss the outcomes, including the difference between Richter and modified Mercalli scales.
Step 3: Explanation	10	(6) The teacher and students discuss the limitation of the Richter scale as the Local scale, and the origin of the Moment magnitude scale. (7) Students discuss the shaking by truck moving and how many earthquakes in the World in a day.
Step 4: Elaboration	15	(8) The teacher and students discuss the brightness scales of the stars, and the sound intensity.
Step 5: Evaluation	5	(9) Students conclude own ideas.

ชื่อ..นามสกุล...........................
ชั้น.....................เลขที่.....................

ใบงานที่ 5 เรื่อง ขนาดและความรุนแรงแผ่นดินไหว

A

วันนี้ (9 พ.ย.) ผู้สื่อข่าวรายงานว่า เกิดเหตุแผ่นดินไหววัดความรุนแรงได้ 6.7 ริกเตอร์ ที่เกาะซัมบาว่าของอินโดนีเซีย ในวันนี้ ขณะที่รายงานเบื้องต้นระบุว่า มีผู้บาดเจ็บอย่างน้อย 38 คน และอาคารหลายแห่งได้รับความเสียหาย

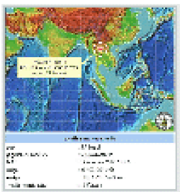
ด้านสำนักงานสำรวจทางธรณีวิทยาของสหรัฐ ระบุว่า แผ่นดินไหวเกิดขึ้นเมื่อเวลา 02.41 น. ตามเวลาท้องถิ่น ซึ่งใกล้เคียงกันตามเวลาในไทย โดยมีศูนย์กลางการเกิดอยู่ทางตะวันออกของเกาะซัมบาว่า ห่างจากกรุงจาการ์ต้าประมาณ 1,300 กิโลเมตร และลึกลงไปในทะเล 18 กิโลเมตร ทั้งยังรับความรู้สึกถึงแรงสั่นสะเทือนได้ที่เกาะลอมบ็อค ซึ่งเป็นสถานที่ท่องเที่ยวที่สำคัญอีกด้วย

B

กทม.

วันที่ 16 พฤษภาคม 2550 เวลา 16:31 น. | จำนวนผู้อ่าน 6319 คน ผู้โหวต 6 คน
คะแนนข่าว ★★★★☆
ขนาดตัวอักษร ก ก ก

ชาวกรุงแตกตื่น แผ่นดินสะเทือน!



เมื่อเวลา 16.10 น. ผู้สื่อข่าวรายงานด่วน ว่า ประชาชนที่ทำงานในตึกสูง ย่านเพลินจิต ย่านสีลม และหลายจุดในพื้นที่กรุงเทพมหานคร ได้รับแรงสั่นสะเทือน กระทั่งโคมไฟเพดานสั่นไหว สร้างความตื่นตระหนกให้กับพนักงานที่ทำงานในตึกดังกล่าว ขณะที่ ตึกยูบีซี 2 ใกล้สถานีรถไฟฟ้าพร้อมพงษ์ บริเวณใกล้ห้างสรพพสินค้าเอ็มโพเรียม ได้สั่งพนักงานอพยพออกจากตึก นอกจากนี้ยังได้รับรายงานแผ่นดินไหว ชาวเชียงใหม่ เชียงราย น่านได้รับแรงสั่นสะเทือนด้วยเช่นกัน

C

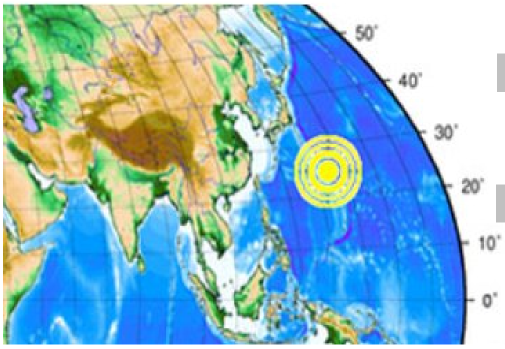
แผ่นดินไหวเนวาดาทำให้ศูนย์กลางประวัติศาสตร์เสียหาย ไฟไหม้ ประปาแตก

โดย ผู้จัดการออนไลน์ 22 กุมภาพันธ์ 2551 09:46 น.

เกิดแผ่นดินไหวอย่างรุนแรงในรัฐเนวาดาซึ่งทำให้ศูนย์กลางด้านประวัติศาสตร์ที่เมืองเวลส์ได้รับความเสียหายและทำให้ประชาชนหลายคนได้รับบาดเจ็บ เมื่อเช้าวานนี้ แต่อย่างไรก็ตาม แผ่นดินไหวดังกล่าวไม่เป็นอุปสรรคต่อการทำเหมืองที่ตั้งอยู่ในบริเวณใกล้เคียงแต่ทำให้การทำเหมืองดังกล่าวชะงักไปเป็นระยะเวลาสั้นๆ เท่านั้น

นอกจากนี้ แผ่นดินไหวซึ่งวัดได้ 6.0 ริกเตอร์ ได้ทำให้เกิดไฟไหม้และท่อประปาแตก ตลอดจนทำให้น้ำหยุดไหลไปชั่วระยะเวลาหนึ่ง

D



กลางดึกที่ผ่านมา เกิดแผ่นดินไหวขนาด [redacted]นอกชายฝั่งทาง [redacted]

สำนักข่าวต่างประเทศรายงานว่า เกิดเหตุแผ่นดินไหว [redacted]นอกชายฝั่งทางตอนใต้ [redacted]แต่จนถึงขณะนี้ ยังไม่มีรายงานเกี่ยวกับความเสียหายใดๆ หรือการสูญเสียชีวิตและคนเจ็บ รวมทั้งไม่มีคำเตือนเกี่ยวกับคลื่นยักษ์สึนามิ

E

แผ่นดินไหว[redacted]เกาะมาร์ตินิค ทำอาคารถล่ม (30 พ.ย. 50)

เกิด**แผ่นดินไหว**อย่างรุนแรงที่เกาะมาร์ตินิคของฝรั่งเศสทำให้อาคารแฝดหลังถล่มหนึ่งลงมาและทำให้มีผู้ได้รับบา และทำให้มีผู้ได้รับบาดเจ็บสาหัสอย่างน้อย 2 ราย.....อ่านต่อคลิกที่นี่

ให้นักเรียนเรียงลำดับเหตุการณ์เหล่านี้ (A-E) ที่มี**ขนาดแผ่นดินไหวจากมากไปน้อย**

ใบความรู้ที่ 6 เรื่อง มาตราวัดขนาดและความรุนแรงของแผ่นดินไหว

เมื่อเกิดปรากฏการณ์แผ่นดินไหวขึ้น ข้อมูลหลักๆ ที่นักวิทยาศาสตร์ทำการศึกษา ได้แก่ ศูนย์เกิดแผ่นดินไหว, จุดเหนือศูนย์เกิดแผ่นดินไหว, วัน เวลาที่เกิด, และความเข้มของการเกิดปรากฏการณ์นี้ สำหรับความเข้มนี้มักมีการกล่าวถึงใน 2 แบบหลักๆ ได้แก่

1) ขนาดของแผ่นดินไหว **(Earthquake Magnitude)** และ 2) ความรุนแรงแผ่นดินไหวในแง่ความเสียหายที่ปรากฏให้เห็นที่พื้นโลก **(Earthquake Intensity)**

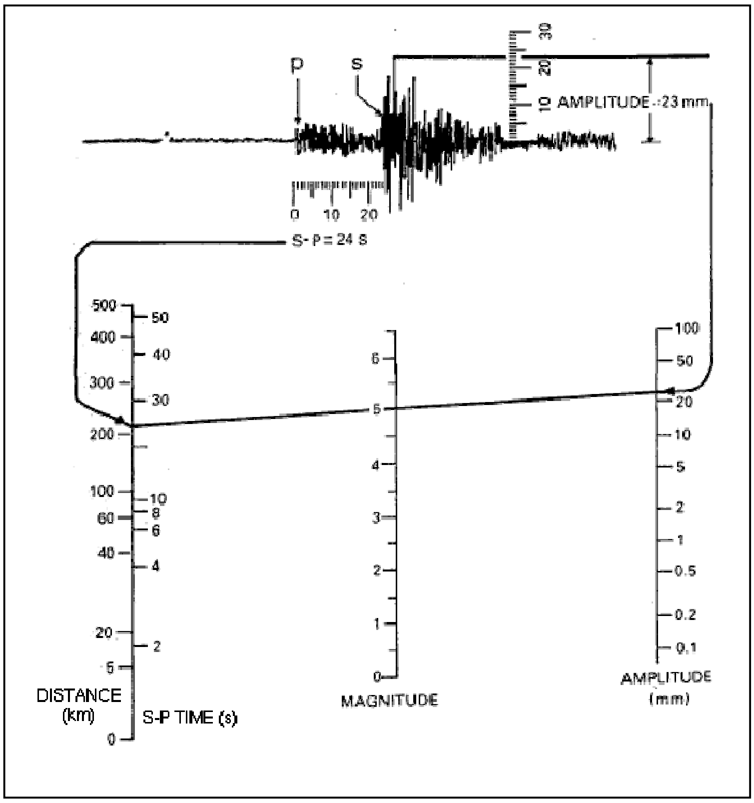
1) ขนาดของแผ่นดินไหว

(อ้างอิง: http://www.geo.mtu.edu/UPSeis/intensity.html)

รูปที่ 6.1 ชาร์ล ฟรานซิส ริกเตอร์ (Charles Francis Richter ; 1900 –1985)

ขนาดของแผ่นดินไหว วัดจากปริมาณพลังงานที่ถูกปล่อยออกมาจากศูนย์เกิดแผ่นดินไหว เมื่อเกิดแผ่นดินไหวขึ้น ซึ่งมีหน่วยที่ใช้วัดหลายแบบ แต่ที่มักได้ยินอยู่บ่อยๆ คือ **หน่วยริกเตอร์ (Richter Magnitude Scale)** ซึ่งตั้งขึ้นโดยนักแผ่นดินไหวชาวอเมริกัน ชื่อ ชาร์ล ฟรานซิส ริกเตอร์ ในช่วงปีค.ศ. 1930 อีกทั้งยังเป็นคนแรกที่คิดค้นสูตรการวัดขนาดแผ่นดินไหวด้วย (รูปที่ 6.1) หน่วยริกเตอร์นี้ สร้างขึ้นมาจากการวัดขนาดของคลื่นแผ่นดินไหวในบริเวณที่ห่างออกไปไม่เกิน 1,000 กิโลเมตรจากศูนย์เกิดแผ่นดินไหวบริเวณแคลิฟอร์เนีย สหรัฐเมริกา โดยอาศัยเครื่องวัดแผ่นดินไหวแบบเกลียวบิด วูด แอนเดร์สัน (Wood–Anderson Torsion Seismometer) ดังนั้นในบางครั้งหน่วยหน่วยริกเตอร์นี้ จึงมักมีชื่อเรียกอีกอย่างหนึ่งว่า **Local Magnitude (M_L)** หน่วยริกเตอร์ถูกสร้างขึ้นมาจากเลขล็อกกาลิทึม ฐานสิบ ดังนั้น ค่าริกเตอร์แต่ละค่าที่ต่างกันหนึ่งจึงแสดงถึงแอมพลิจูดที่ต่างกันของคลื่นเป็นสิบเท่า สำหรับพลังงานนั้นต่างกันประมาณ 30 เท่า

วิธีการหาขนาดแผ่นดินไหวตามหน่วยริกเตอร์ สามารถทำได้โดยการลากกราฟจากแอมพลิจูดสูงสุดของคลื่น S ไปยังจุดตัดในแกนระยะห่างระหว่าง P กับ S ที่กระดาษบันทึกสัญญาณคลื่นแผ่นดินไหวบันทึกได้ จะทำให้ได้ขนาดแผ่นดินไหวในหน่วยริกเตอร์ (รูปที่ 6.2) หรืออาจจะคำนวณโดยอาศัยสมการคือ $M_L = \log_{10} A - \log_{10} A_0$ เมื่อ A เป็น แอมพลิจูดสูงสุดที่บันทึกได้ด้วยเครื่องมือวัดแบบเดียวกัน และ A_0 เป็นค่ามาตรฐานสำหรับพื้นที่หนึ่งๆ ที่เกิดแผ่นดินไหวขึ้น ซึ่งจะมีบอกไว้ในตารางมาตรฐาน



รูปที่ 6.2 การหาขนาดของแผ่นดินไหวในหน่วยริกเตอร์ โดยวิธีการลากกราฟ

แม้หน่วยวัดขนาดแผ่นดินไหวแบบริกเตอร์จะมีการใช้กันอย่างแพร่หลาย แต่ก็มีข้อจำกัดที่เลี่ยงไม่ได้นั่นคือ หน่วยริกเตอร์จะได้ค่าที่แม่นยำเมื่อเป็นข้อมูลที่มาจากเครื่องมือวัดเฉพาะแบบและมีค่าอยู่ในช่วงไม่เกิน 1,000 กิโลเมตร อีกทั้งเมื่อเกิดแผ่นดินไหวขนาดใหญ่มากๆ ค่าที่คำนวณได้จะคลาดเคลื่อน โดยหน่วยริกเตอร์สามารถวัดได้แม่นยำที่ขนาดไม่เกิน 6.5 ริกเตอร์เท่านั้น ดังนั้นในเวลาต่อมานักวิทยาศาสตร์จึงได้คิดหน่วยวัดขนาดแผ่นดินไหวแบบอื่นขึ้นมาใช้แทน ซึ่งมีหลายๆ แบบด้วยกันหน่วย Body wave magnitude (m, mb) ที่สร้างขึ้นโดย กูเท็นเบอร์กและริกเตอร์ ในปีค.ศ. 1956, หน่วย Surface wave magnitude (M_s) สร้างโดยองค์กรด้านแผ่นดินไหว IASPEI, หน่วย Energy magnitude (M_e) สร้างโดยเชาย์และโบทไวห์ท ในปีค.ศ. 1995 แต่ที่ได้รับความนิยมมากสุดและเชื่อกันว่าให้ข้อมูลที่ถูกต้องมากสุดในปัจจุบันคือ หน่วย **Moment Magnitude Scale (M_W)** ที่สร้างขึ้นโดยแฮงค์และคานาโมริ ในปี ค.ศ. 1979 ซึ่งหน่วย M_W นี้จะคำนวณโดยอาศัยลักษณะของรอยเลื่อนที่เกิดแผ่นดินไหวด้วย เช่น พื้นที่หน้าตัด และระยะทางที่เลื่อนออกไป อีกทั้งหน่วย M_W นี้ วัดขนาดแผ่นดินไหวได้ตรงกับหน่วยริกเตอร์ในช่วงไม่เกิน 6.5 ริกเตอร์ ถ้ามากกว่านี้หน่วยริกเตอร์จะวัดค่าได้น้อยกว่า

2) ความรุนแรงแผ่นดินไหว

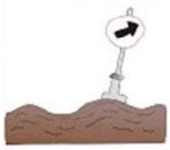
การบอกความรุนแรงในการเกิดแผ่นดินไหวที่ทำให้เห็นภาพชัดเจนคือการบอกโดยอาศัยผลกระทบที่ปรากฏให้คนเห็นได้ นักแผ่นดินไหวกลุ่มแรกคือ เดอ ฟอสสิ ชาวอิตาเลียนและฟอเรล ชาวสวิตเซอร์แลน เป็นกลุ่มแรกที่เสนอแนวคิดนี้ โดยสร้างเป็นหน่วยบอกความเสียหายของแผ่นดินไหวชื่อ **Rossi-Forel scale (R.F.)** ซึ่งมีลักษณะเป็นเลขโรมันจาก I-X ในเวลาต่อมามีการนำมาปรับโดยนักธรณีวิทยาชาวอิตาเลียน ชื่อ จูเซป เมอร์คัลลี (รูปที่ 6.3) จนกลายเป็นหน่วยบอกความเสียหายของการเกิดแผ่นดินไหวที่ใช้กันอยู่คือ **Modified Mercalli Scale (M.M.)** ซึ่งมีลักษณะเป็นเลขโรมันจาก I-XII เรียงลำดับความเสียหายจากน้อยไปมาก (รูปที่ 6.4) เช่น ระดับที่คนทั่วไปเริ่มรู้สึกตัวอยู่ที่ประมาณ II หรือ III, ระดับ V จะทำให้จาน ชาม และหน้าต่างแตกกระจาย และที่ระดับ XII ทุกสิ่งทุกอย่างถูกทำลายหมด เป็นต้น

(อ้างอิง:http://www.geo.mtu.edu/UPSeis/intensity.html)

รูปที่ 6.3 จูเซป เมอร์คัลลิ (Giuseppe Mercalli ;1850-1914)

หน่วยบอกความเสียหายแผ่นดินไหวมักไม่ค่อยได้รับความนิยมโดยทั่วไป แม้จะมีจุดเด่นอยู่ตรงที่เข้าใจได้ง่าย แต่ทั้งนี้มันมีข้อบกพร่อง เช่น เมื่อเกิดแผ่นดินไหวขึ้นหนึ่งครั้ง หน่วยบอกความเสียหายจะมีได้หลายค่า ขึ้นกับว่าบริเวณนั้นอยู่ใกล้หรือไกลจากศูนย์เกิดแผ่นดินไหว ดังนั้นค่า Modified Mercalli Scale (M.M.) ที่กล่าวถึงจึงต้องเป็นของเฉพาะบริเวณเท่านั้น ชนิดของวัสดุที่เป็นตัวประเมินความเสียหายมีโครงสร้างต่างกันในแต่ละท้องถิ่น เช่น ความเข็งแรงของโครงสร้างอาคาร สิ่งปลูกสร้าง อีกทั้งสำหรับบริเวณที่มีดินอ่อนตัว จะทำให้เกิดความเสียหายได้ง่ายกว่าบริเวณอื่น ดังนั้นเพื่อหลีกเลี่ยงการตีความที่อาจไม่ตรงกัน หน่วยบอกความเสียหายจึงมักไม่นิยมใช้ในปัจจุบัน

รูปที่ 6.4 ระดับความรุนแรงแผ่นดินไหว ตามมาตรา Modified Mercalli Scale (M.M.)

ความรุนแรง	สภาพของแผ่นดินไหว		ความรุนแรง	สภาพของแผ่นดินไหว	
I	คนธรรมดาจะไม่รู้สึก แต่เครื่องวัดสามารถตรวจจับได้		**VII** แรงมาก	ฝาห้องแยก ร้าว กรุเพดานร่วง	
II อ่อน	คนที่มีความรู้สึกไว จะรู้สึกว่าแผ่นดินไหวเล็กน้อย		**VIII** ทำลาย	ต้องหยุดขับรถยนต์ ตึกร้าว ปล่องไฟพัง	
III เบา	คนที่อยู่กับที่ จะรู้สึกว่าพื้นสั่น		**IX** ทำลายสูญเสีย	บ้านพังตามแถบรอยแยกของแผ่นดิน ท่อน้ำ ท่อก๊าสขาดเป็นตอน ๆ	
IV พอประมาณ	คนที่สัญจรไปมา จะรู้สึกได้		**X** วินาศภัย	แผ่นดินแตก ตึกแข็งแรงพัง รางรถไฟคดโค้ง ดินลาดเขาเคลื่อนตัวหรือถล่มตอนชัน ๆ	
V ค่อนข้างแรง	คนที่นอนหลับ ตกใจตื่น		**XI** วินาศภัยใหญ่	ตึกถล่ม สะพานขาด ทางรถไฟ ท่อน้ำ และสายไฟใต้ดินเสียหาย แผ่นดินถล่ม น้ำท่วม	
VI แรง	ต้นไม้สั่น บ้านแกว่ง สิ่งปลูกสร้างบางชนิดพัง		**XII** มหาวิบัติ	ทุกสิ่งทุกอย่างบนพื้นดินแถบนั้นเสียหายโดยสิ้นเชิง พื้นดินเคลื่อนตัวเป็นลูกคลื่น	

(อ้างอิง: http://teenet.tei.or.th/Knowledge/disaster.html)

APPENDIX E
THE SATISFACTION QUESTIONNAIRE
OF THE EARTHQUAKE LEARNING MODULE

This questionnaire is a part of the education research to promote Thai students understanding of earthquakes. The following statements are about the teaching and learning by using the earthquake learning module constructed by the researchers. No information of the answers will be given to instructors or assessing the course. Please mark √ in the following table to show how much you agree or disagree with each statement.

I agree to participate in this study.
Signature………………………………….
(…………………………………)

1: Strongly Disagree	2: Disagree	3: Undecided	4: Agree	5: Strongly Agree

	This tool helps me to learn the earthquakes.	1	2	3	4	5
1	Animation pictures such as seismic wave animation					
2	The demonstration set such as the convection current demonstration set					
3	Performing experiment such as the simple seismograph activities					
4	Worksheets					
5	Summary documents					
6	Working as groups and discussion					
7	The prediction and demonstration					
8	Real life situations, documentary videos, and news					

9. Other teaching tools/methods that you think it can help you to learn the earthquakes.
………………………………………………………………………………………………………
10. Other suggestions
………………………………………………………………………………………………………

APPENDIX F
THE EARTHQUAKE CONCEPT TEST
(THAI VERSION)

<u>คำชี้แจง</u>

1. แบบประเมินนี้เป็นส่วนหนึ่งของงานวิจัยเพื่อพัฒนาความเข้าใจเรื่องแผ่นดินไหว สำหรับนักเรียน/นักศึกษาในประเทศไทย
2. ผู้วิจัยขอความร่วมมือให้ทุกท่านตอบคำถามทุกข้ออย่างเต็มความสามารถ โดยข้อมูลที่ได้ไม่มีผลต่อคะแนนและการเรียนการสอนของผู้ตอบแบบประเมิน
3. คำถามมีจำนวน 10 ข้อ (4 หน้า) ให้ผู้ตอบแบบประเมินตอบคำถามลงในกระดาษคำตอบที่เตรียมไว้ให้ และใช้เวลาทำ 15-20 นาที

ข้าพเจ้ายินดีให้ความร่วมมือในการตอบแบบประเมินความเข้าใจ เรื่องแผ่นดินไหว

ลงชื่อ..

(...)

กระดาษคำตอบ

1. ____________________	**6.** ____________________
2. ____________________	**7.** ____________________
3. ____________________	**8.** ____________________
4. ____________________	**9.** ____________________
5. ____________________	**10.** ____________________

1) **<u>กำหนดให้</u>** สำหรับแผ่นดินไหวขนาด 5 ริกเตอร์ที่เกิดที่เชียงราย คลื่นแผ่นดินไหวจะเดินทางไปถึงสถานีวัดแผ่นดินไหวที่กาญจนบุรีใช้เวลา 2 นาที **<u>ถามว่า</u>** ถ้าเกิดแผ่นดินไหวที่เชียงรายขนาด 5.5 ริกเตอร์ และเกิดคลื่นแผ่นดินไหวแบบเดียวกันกับคลื่นขนาด 5 ริกเตอร์ เดินทางตามเส้นทางเดิมไปถึงสถานีวัดแผ่นดินไหวกาญจนบุรี คลื่นจะใช้เวลาเดินทางเท่ากันหรือไม่ เพราะเหตุใด

A. เท่ากัน เพราะคลื่นแผ่นดินไหวทั้งสอง มีขนาดต่างกันไม่มาก
B. เท่ากัน เพราะคลื่นแต่ละขนาดจะใช้เวลาเท่ากัน ถ้าคลื่นเดินทางตามเส้นทางเดิม
C. ไม่เท่ากัน เพราะคลื่นขนาด 5 ริกเตอร์ มีขนาดเล็กกว่าจะใช้เวลาเดินทางน้อยกว่า
D. ไม่เท่ากัน เพราะคลื่นขนาด 5.5 ริกเตอร์ มีการสั่นรุนแรงกว่าจะเดินทางได้เร็วกว่า

2) เมื่อคลื่นแผ่นดินไหวคลื่นแรกเดินทางผ่านตัวกลาง เช่น ดิน หิน จะทำให้เกิดการสั่นของอนุภาคตัวกลาง ซึ่งมีลักษณะคล้ายคลึงกับการสั่นของตัวกลางคลื่นใด

A. แสง
B. คลื่นน้ำ
C. คลื่นเสียง
D. คลื่นในเส้นเชือก

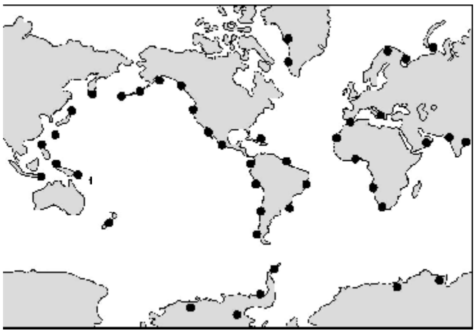
3) คำกล่าวใดสรุปความสัมพันธ์ระหว่างภูเขาไฟ แผ่นดินไหวขนาดใหญ่ และ แผ่นธรณีภาค ได้**<u>ถูกต้องที่สุด</u>**

A. ทั้งภูเขาไฟและแผ่นดินไหวขนาดใหญ่มักเกิดในเขตร้อนใกล้กับแผ่นธรณีภาค
B. ทั้งภูเขาไฟและแผ่นดินไหวขนาดใหญ่มักเกิดตามแนวขอบของแผ่นธรณีภาค
C. แผ่นดินไหวขนาดใหญ่มักเกิดตรงใจกลางของแผ่นธรณีภาค แต่ภูเขาไฟมักเกิดตามแนวขอบของแผ่นธรณีภาค
D. ภูเขาไฟมักเกิดบนเกาะ แต่แผ่นดินไหวขนาดใหญ่มักเกิดในแผ่นดิน ทั้งภูเขาไฟและแผ่นดินไหวขนาดใหญ่มักเกิดใกล้กับแผ่นธรณีภาค

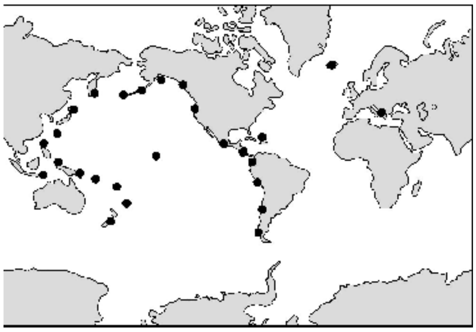
4) คลื่นแผ่นดินไหวชนิดหนึ่ง เดินทางผ่านชั้นดินกับชั้นหินซึ่งหนาเท่ากัน คลื่นแผ่นดินไหวนี้จะใช้เวลาเดินทางผ่านตัวกลางทั้งสองเท่ากันหรือไม่ เพราะเหตุใด

A. เท่ากัน เพราะเป็นคลื่นแผ่นดินไหวชนิดเดียวกัน
B. ไม่เท่ากัน เพราะดินจะสั่นได้รุนแรงกว่า คลื่นจึงถูกส่งผ่านไปได้เร็วกว่า
C. ไม่เท่ากัน เพราะหินมีความหนาแน่นกว่า คลื่นจึงเดินทางผ่านได้เร็วกว่า
D. ข้อมูลไม่เพียงพอ เพราะต้องดูว่าแผ่นดินไหวขนาดเท่ากันหรือไม่

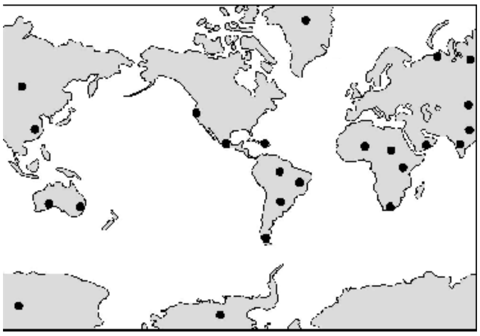
5) แผนที่ข้างล่างนี้แสดงส่วนที่เป็นผืนแผ่นดินและมหาสมุทร โดยมีสัญลักษณ์ แสดงแนวแผ่นดินไหวของโลก นักเรียนคิดว่าแผนที่ใดข้างล่างนี้ที่แสดง**แนวแผ่นดินไหวส่วนใหญ่ของโลก**ได้ใกล้เคียงที่สุด



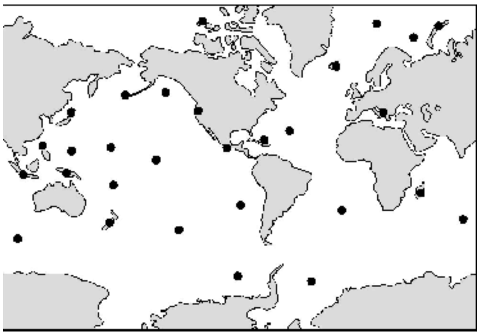
(A) ตามแนวรอยต่อระหว่างผืนแผ่นดินและมหาสุมทร



(B) ตามแนวขอบของมหาสมุทรแปซิฟิก



(C) ในผืนแผ่นดิน



(D) ตามเกาะต่างๆ ในมหาสมุทร

6) ถ้าเกิดแผ่นดินไหวขนาด 4 ริกเตอร์ที่กาญจนบุรี (A) สถานีวัดแผ่นดินไหวที่เชียงราย (B) และสงขลา(C) จะตรวจพบแผ่นดินไหวคลื่นแรกได้พร้อมกันหรือไม่ เพราะเหตุใด (เมื่อระยะห่างระหว่างกาญจนบุรี - เชียงราย และกาญจนบุรี – สงขลา เท่ากัน)

A. พร้อมกัน เพราะแผ่นดินไหวขนาดเดียวกัน

B. พร้อมกัน เพราะระยะทางที่คลื่นเดินทางผ่านเท่ากัน

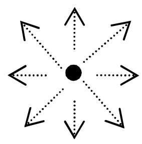
C. ไม่พร้อมกัน เพราะสถานีทั้งสองอยู่คนละทิศกัน

D. ไม่พร้อมกัน เพราะเส้นทางที่คลื่นใช้ต่างกัน

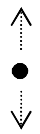
<u>คำชี้แจง</u> คำถามที่ 7 และ 8 ให้นักเรียนเลือก A ถึง D ตอบคำถาม

กำหนดให้ ● (จุดกลม) แทน อนุภาคตัวกลางของคลื่นแผ่นดินไหว เช่น ดิน หิน

·········> (ลูกศร) แทน ทิศการเคลื่อนที่ของอนุภาคตัวกลาง

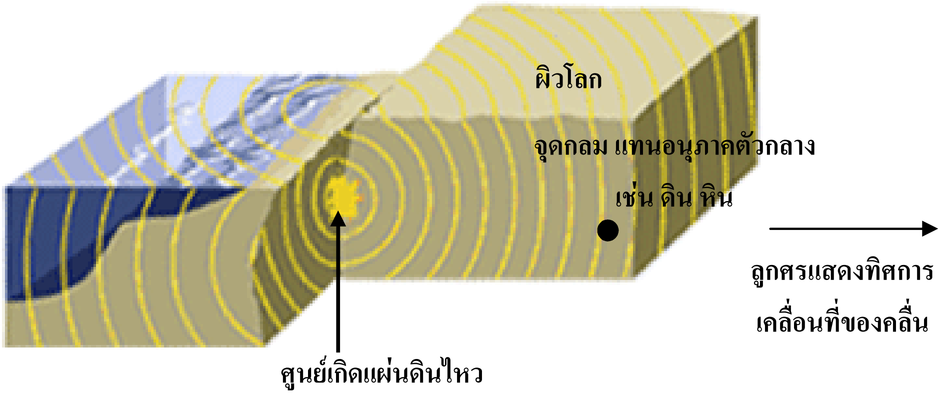
(A)  อนุภาคตัวกลางเคลื่อนที่ออกทุกทิศ

(B)  อนุภาคตัวกลางเคลื่อนที่ไปข้างหน้าเป็นเส้นทางโค้ง

(C)  อนุภาคตัวกลางเคลื่อนที่ขึ้น - ลง กลับไปกลับมา

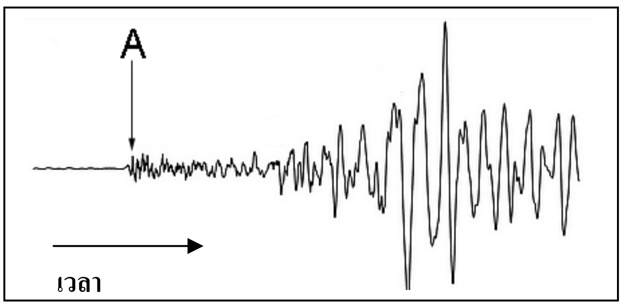
(D)  อนุภาคตัวกลางเคลื่อนที่ซ้าย - ขวา กลับไปกลับมา

7) จาก***ภาพแสดงศูนย์เกิดแผ่นดินไหวและคลื่นแผ่นดินไหว*** ถ้าทิศการเคลื่อนที่ของคลื่นแผ่นดินไหวเป็นตามลูกศร เมื่อคลื่นแผ่นดินไหวคลื่นแรกเคลื่อนที่ผ่านตัวกลาง **<u>อนุภาคตัวกลาง เช่น ดิน หิน (แทนด้วย จุดกลม) เคลื่อนที่อย่างไร</u>**



8) จากภาพ***กระดาษบันทึกสัญญาณคลื่นแผ่นดินไหว*** ตำแหน่ง A บนกระดาษเป็นสัญญาณคลื่นแผ่นดินไหวแรกที่บันทึกได้ ถ้ากำหนดให้คลื่นแผ่นดินไหวเดินทางจากซ้ายไปขวาของกระดาษ คลื่นแผ่นดินไหวแรกที่บันทึกได้บนกระดาษนี้ทำให้**<u>อนุภาคตัวกลาง เช่น ดิน หิน เคลื่อนที่อย่างไร เมื่อคลื่นเดินทางผ่าน</u>**

ซ้าย



ขวา

<u>คำชี้แจง</u> คำถามที่ 9 และ10 ให้ใช้ข้อมูล I ถึง VI ตอบคำถาม

I เกิดดินถล่ม	**IV** อยู่ในแนวรอยเลื่อนที่มีพลัง
II มีภูมิประเทศเป็นเกาะ	**V** อยู่ตรงรอยต่อของแผ่นธรณีภาค
III มีการระเบิดของภูเขาไฟ	**VI** มีตำแหน่งอยู่ใกล้แนวศูนย์สูตร

9) ปัจจัยใดบ้างที่เป็นสาเหตุของการเกิดแผ่นดินไหวของโลก

A. I , II และ IV

B. I , V และ VI

C. II , III และ V

D. III , IV และ V

10) เพราะเหตุใดคลื่นสึนามิจึงมักเกิดขึ้นบริเวณมหาสมุทรแปซิฟิก

A. I

B. II

C. V

D. VI

APPENDIX G
THE EARTHQUAKE CONCEPT TEST
(ENGLISH VERSION)

<u>Description</u>

1. This test is a part of the education research to promote Thai students understanding of earthquakes.
2. Please answer the following questions to the best of your ability. No information of the answers will be given to instructors or assessing the course.
3. This test consists of 10 questions (4 pages). The volunteer students should respond in the answer sheet, and take around 15-20 minutes to complete the test.

I agree to participate in this study.

Signature……………………………………

(…………………………………..)

ANSWER SHEET

1. ________________	**6.** ________________
2. ________________	**7.** ________________
3. ________________	**8.** ________________
4. ________________	**9.** ________________
5. ________________	**10.**________________

Q1. <u>Situation:</u> the ***5*** Richter earthquake occurs at ChiangRai and its seismic waves propagate to a seismic station at Kanchanaburi for 2 minutes. If the ***5.5*** Richter earthquake occurs at ChiangRai and its seismic waves propagate through the same medium of that of the former to the same seismic station at Kanchanaburi, **<u>does it spend times for 2 minutes? Why?</u>**

(A) Yes, because both have a little different magnitudes.
(B) Yes, because both propagate through the same medium.
(C) No, because the 5 Richter earthquake is a smaller magnitude; it spends less time.
(D) No, because the 5.5 Richter earthquake is more severe one; it moves faster.

Q2: When the first earthquake wave (P-wave) propagates through a soil or rock particle, it will shake the particle like what other kinds of waves?

(A) Light
(B) Water waves
(C) Sound waves
(D) Waves on a string

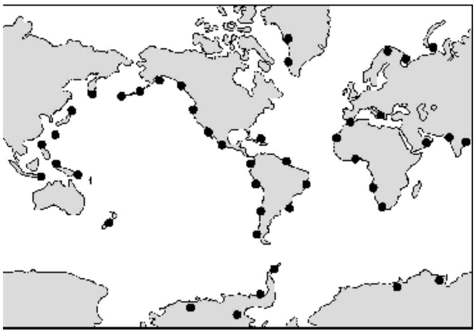
Q3. Which of the following responses **<u>best summarizes</u>** the relationship between volcanoes, large earthquakes, and tectonic plates?

(A) Volcanoes and large earthquakes both typically occur in warm climates of tectonic plates
(B) Volcanoes and large earthquakes both typically occur along the edges of tectonic plates
(C) Volcanoes typically occur in the center of tectonic plates and large earthquakes typically occur along the edges of tectonic plates
(D) Volcanoes typically occur on islands, earthquakes typically occur on continents, and both occur near tectonic plates

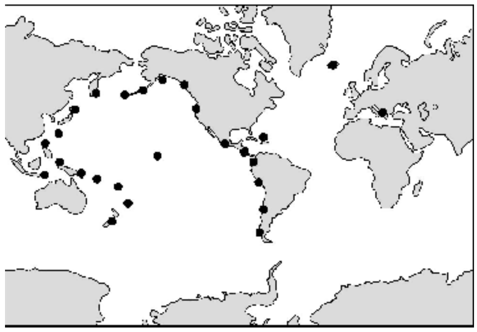
Q4. <u>Situation:</u> A seismic wave is moving through the soil layer. If this seismic wave moves through the rock layer (the equivalent thickness of the soil layer), **<u>does it spend equal times? Why?</u>**

(A) Yes, because it is the same seismic wave.
(B) No, because the soil particle vibrates more violent; its wave moves faster.
(C) No, because the rock is denser than soil; its wave moves faster.
(D) Not enough information, it depends on the magnitude of earthquakes.

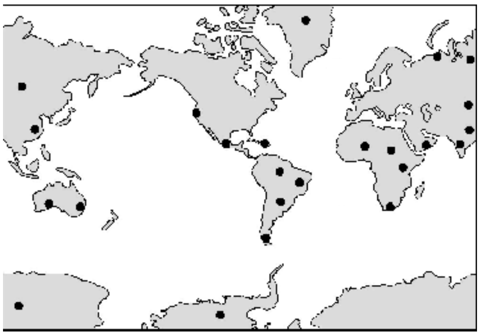
Q5. The following maps show the position of the earth's continents and oceans. The ● on each map mark the locations of the earthquake region. Which map most closely represents **<u>the area of frequent earthquakes of the world</u>**?



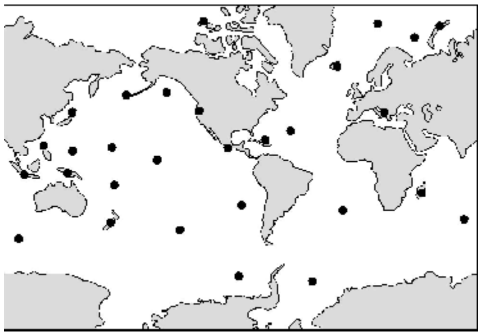
(A) Mostly along the margins of continents and oceans



(B) Mostly along the margins of the Pacific Ocean



(C) Mostly on continents



(D) Mostly on islands

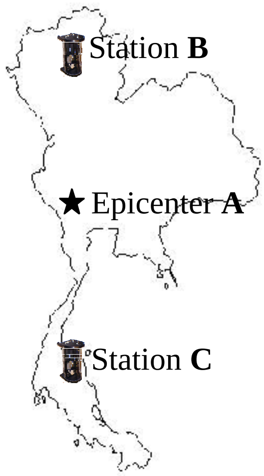
Q6. If the 4 Richter earthquake occurs at Kanchanaburi (A), do the two seismic stations (at ChiangRai (B) and SongKhla (C)) detect the P-waves at the same time? Why? (The distances between Kanchanaburi-ChiangRai, and Kanchanaburi-SongKhla are equal.)

(A) Yes, because it is the same 4 Richter earthquake.

(B) Yes, because the distances are equal.

(C) No, because both seismic stations have different directions.

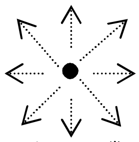
(D) No, because the media of the seismic waves are different.

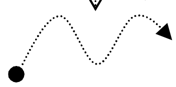


Description: Here are choices (A-D) for Q7 and Q8**.** Choose one that applies

Assume that ● (a dot) represents a particle of earthquake wave medium (i.e. rock or soil particle)

·······> (an arrow) represents the direction of the particle motion

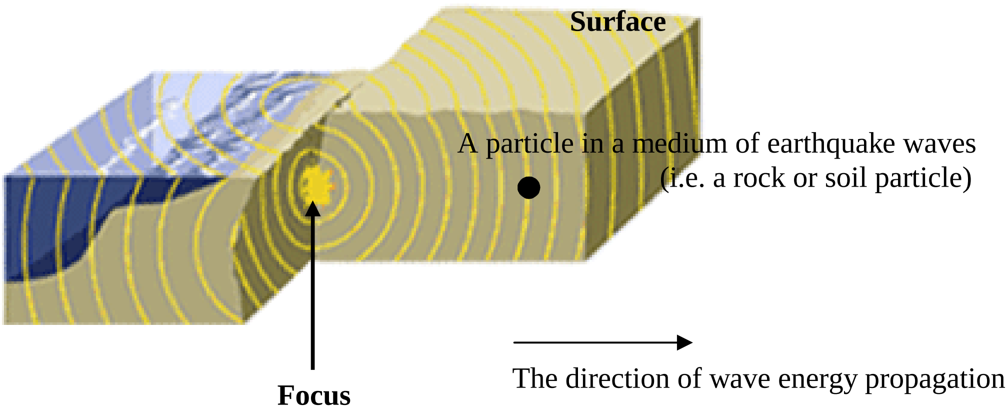
(A)  The particle spreads in all directions.

(B)  The particle moves forward like a sine wave motion.

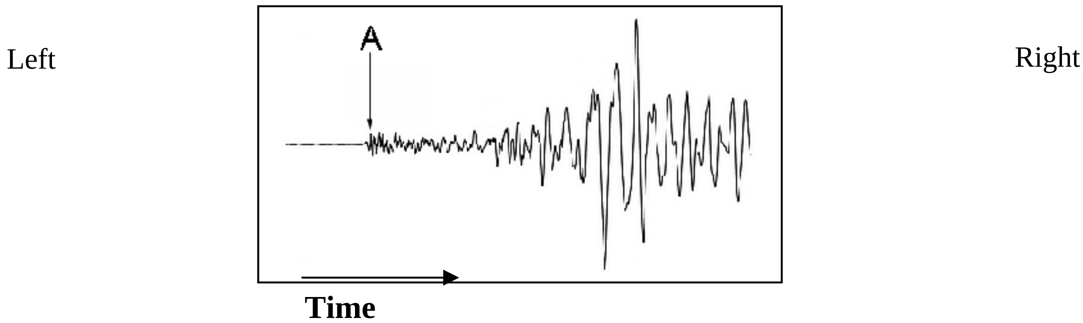
(C)  The particle vertically moves back and forth.

(D)  The particle horizontally moves back and forth.

Q7: Consider a particle in a medium of earthquake waves (i.e. a rock or soil particle) (shown by a dot " ● " in the following figure). **Which response best represents the particle motion at the P-wave arrival?** (The direction of wave energy propagation is shown by the arrow below)



Q8: Consider the position A on the following seismogram. It is the first earthquake wave signal recorded on the seismogram. Assume that the direction of wave energy propagation is from the left to the right hand side of the figure; **which response best represents the particle motion when the first earthquake wave arrives?**



Description: Here is information (I-VI) for Q9 and Q10.

I	Soil Sliding	IV	Active Faults
II	Islands	V	Plate Boundaries
III	Volcanic Eruption	VI	Equator Zone

Q9. Which factors are the causes of earthquakes?

(A) I, II and IV

(B) I, V and VI

(C) II, III and V

(D) III, IV and V

Q10. Why Tsunamis often occur along the margins of the Pacific Ocean?

(A) I

(B) II

(C) V

(D) VI

APPENDIX H

THE EARTHQUAKE CONCEPT TEST KEY

1: B	2: C	3: B	4: C	5: B
6: D	7: D	8: D	9: D	10: C

BIOGRAPHY

NAME	Suttida Rakkapao
DATE OF BIRTH	24 November 1981
PLACE OF BIRTH	Surat Thani, Thailand
INSTITUTIONS ATTENDED	Prince of Songkla University, 2000-2003 Bachelor of Science (Physics) (Hons.) Srinakharinwirot University, 2004 Diploma (Teaching Profession) Mahidol University, 2005-2009 Doctor of Philosophy (Science and Technology Education)
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PUBLICATION	Rakkapao, S., Arayathanitkul, K., & Pananont, P. (2009). Thai University Students' Prior Knowledge about P-wave Generated Particle Motion. *Journal of Geoscience Education,* 57(4), 286-299.