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THESIS

TEACHING AND LEARNING ABOUT ENERGY: USING SCIENCE,
TECHNOLOGY AND SOCIETY (STS) APPROACH

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This research aims to enhance energy teaching and learning through STS approach in Khon Kaen province, Thailand. The participants consist of 172 Grade 9 students including the 47 students of the school A (a university school), the 49 students of the school B (the city school), the 47 students of the school C (a small town school), and the 29 students of the school D (a rural school).

The research was designed in three phases under paradigm of interpretive research. These three phases include exploration, intervention, and evaluation phase. The exploration phase, explored what students' ideas about energy concepts and energy related technological and societal issues, and what teachers' understanding of pedagogical knowledge; and energy concepts. The QSEC and QSETS were employed for exploring the school A, B, C, and D students' ideas. The QTEP was employed for exploring the school B, C, and D teachers' ideas. The given ideas from these questionnaires were be categorized. Each category of given ideas were discussed to develop assumption for developing the STS energy unit and the program of enhancing the STS energy teaching. The intervention phase was the initially trialing the STS energy unit by the researcher in the school A. The initial STS energy unit was developed based on assumption from the four schools students' existing ideas. The results of the initial trialing were monitored with the different instruments including participant observation, the energy test, document analysis, and informal conversational interview. The data analysis was discussed for giving the implications for the further trialing of the evaluation phase. The evaluation phase aimed to evaluate how the unit works through enhancing the STS energy teaching and learning in three different schools including school B, C, and D. The instruments were employed to give these reflections including participant observation, document analysis, energy test, the semantic differential scale of students' reaction in energy unit (SSRE), and an informal conservational interview. Finally, each school reflection will be discussed and then compare and contrast the reflection among three schools to have implications for further research.

Chokchai Yuenyong

Student's signature

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CHAPTER I

INTRODUCTION

This chapter clarifies the significance of the study. The chapter then introduces the research problem, the aim of the research study, the research questions, anticipated outcomes, delimitation of study, and summary.

Significance of the Study

This section outlines the stipulation of the goals of recent educational reform; discusses intervention with the concept of energy conservation, transformation, and degradation in the process of generating power for Grade 9 students. Then, it outlines confusion between everyday use of energy, scientific use and using science relevant and helping students to understand the relationship between science, technology and society. Finally, this section provides a rationale for using science, technology, and society approach.

1. Stipulation of the Goals of Recent Educational Reform

The recent wave of educational reform in Thailand began around 1996 and was influenced by the indicators of inside and outside the school. The indicators outside the school include science and technology, international educational ranking, economic crisis, and way of life (ONEC, 2000a: 2 - 3; Pitiyanuwat & Anantrasirichai, 2002). Thailand needs to rely more on imported technology because of its limited science and technology potential. Thailand lags behind internationally on many major indicators of educational quality and human resource development such as educational capability, academic competitiveness, competitiveness in science and technology, and international science achievements. Consequently, it is necessary for Thailand to accelerate her development to keep pace with the science and technology changes that move ahead rapidly and enable to link globalization (Johnson, 1992; ONEC, 1998; Pitiyanuwat & Anantrasirichai, 2002). The indicators in school system

include learners' lack of desirable attributes, a lack of meaningful teaching and learning, and a lack of a supportive environment in the school. Teaching emphasises following textbooks rather than guiding learners to make links between local wisdom and modern technology. The process is devoted more to rote learning than to practice thinking and character building; or to practice life-long learning. This seems that teaching and learning give the learner only knowledge rather than a chance for practice in analytical thinking, self-expression and acquiring knowledge themselves (ONEC, 1998a).

With the educational reform, the National Education Act (1999) was launched to introduce effective education. The new standards are to be achieved in the year 2007. The curriculum construction changed to become decentralized (ONEC, 2000a; Pitiyanuwat and Anantrasirichai, 2002). The curriculum changed to be school-based. The schools have flexibility to produce a local curriculum but it must be based on the content standard that is prescribed by the Institution for Promoting Science and Technology (IPST) for science content (ONEC, 1999; ONEC, 2000b). One concern of the teaching reform is changing the pedagogic philosophy from teacher-centred to student-centred (ONEC, 1999). The learning emphasis is on a learner-centred approach and life-long learning, so that learning can take place anywhere, at all time, and all levels within learners themselves and outside the classroom (ONEC, 2000a). Students should have chance to be in touch and interact with all around them such as other people, nature and technology; and to apply learning methods to their real life (ONEC, 2002a: 26 - 27).

The goal of Thai science education was addressed along with these crucial aspects of educational reform. The goal of science education aims students to think by considers the relationship between science, technology and society. This goal need people who must understand science in level of multidimensional scientific and technological literacy in order to meet agreement about issues of science technology and society that affect the living across the world (IPST, 2002).

To attain the goal of science education, the science teachers were in general agreement with the need for making science teaching more meaningful by emphasis on student-centred learning and concern life-long learning that should play on the relationship between science, technology and society. However, many teachers in Thailand still do not appreciate the need for change. One of problems of Thailand educational reform is having teachers who are technicians and not professionals. As professionals, they could be expected to understand both the theoretical and the practical nature of theories (ADB, 2002), and this has not been the case. Teachers need to become truly professional practitioners who have the capacity to identify the most appropriate strategy and design learning experiences for specific learning situations. Thai science educators need to discover how to achieve the reform within the constraints teacher ability (Sinarat, 1999), the classroom and examination prescription (ADB, 2002).

Between 1997 and 2000, the researcher was a science and physics teacher at a secondary school in Khon Kaen, Thailand; teaching mainly the topic of energy. As part of the teaching, the students were taken to see how a power plant works, and it seemed that their scientific curiosity was satisfied. This leads to the hypothesis that the students were happy and eager to learn about how electricity is produced, when they saw the real situation and how the engineers and scientists controlled the power plant. This experience deepened the researcher's idea of teaching science as it is relevant to technology and society. This research will use the strategy of presenting the students with examples of energy use in everyday life to make the topic relevant for them.

2. Rationale for Intervention with Energy Concepts

In attempting to teach energy concepts relevant to the students' everyday life or social situation, the researcher tried to look for what the layman ideas of energy use in daily life involve. Watchamul (1998) showed the layman ideas of energy use in Thailand presented in the press, generally relate to electrical energy such as campaigning for saving electrical energy, and the power generation causing of

pollution. There were reports in the press about issues of electrical energy, for example, people protested the Hin Krut and Bo Nok coal power-plant projects in Prachuap Khiri Khan Province because there was a conflict between electrical energy requirements and environmental conservation (The Nation: August 28, 2001; September 5, 2001). The government campaigned for saving energy by means of the Project 'Energy Divide by Two'. This suggests that the layman needs to gain their understanding about energy and skills to make decision concerning these controversies of energy.

In physicists' view, generating power mainly relates to the concept of transformation, conservation and degradation of energy. For example, the concept of conservation, transformation, and degradation energy in relation to steam-powered electricity generation is that thermal energy (from water boiling) is transformed into electric energy, mechanical energy, thermal energy (pollution) and so on; however, the total of energy stays the same (Hobson, 1986).

The term of saving energy relates to the law of energy conservation but, in the scientists' view, these two terms are not the same meaning. The research found that western students (Carr and Kikwood, 1988) and Thai students use the term conservation and saving as having similar meanings in everyday life (Yuenyong et.al., 2005). In the everyday dichotomy between conservation and saving (Carr and Kikwood, 1988), energy conservation has been understood as decreasing the rate at which people convert energy from useful to less useful forms (Duit, 1984). But, as a scientific term, energy conservation refers to energy which can be transformed from one form to another while the total amount of energy stays the same (Hobson, 1986). This dichotomy seems to also occur in Thailand, for example, the government campaigned for saving energy as the Project Energy Divide By Two but the terms saving and conservation are interchangeable in common usage.

With the dichotomy of saving and conservation energy, the degradation concept as the simple notion of Entropy needs to be introduced at the lower grades, e.g. Grades 7 – 10, in order to provide basic ideas of learning energy to distinguish

this dichotomy (Duit, 1984). The confusion of this dichotomy could come from textbook definitions and teacher's expression. Thai science text book also gave a vague definition of energy as mechanical processes: "energy is the ability (or capacity) to do work" (IPST, 1990). However, at the same time, students learn about the work done against friction which produces thermal energy or heat. From the Second Law of Thermodynamics, it is not true that the thermal energy of a system is equal to its capacity to do work (Trumper, 1990a). Physics instruction should not convince students that the principle of conservation of energy is valid by using idealised mechanics processes. It should spend time on introducing the topic of energy degradation (Duit, 1984); because when energy is converted during a process the amount of energy is conserved. Although the amount of energy has not changed, the 'useful value' of the energy has decreased and it is difficult to reverse to high useful value form of energy. For instance, kinetic energy, while current is flowing (electrical energy) is of high value. It is possible to convert them, in principle totally, into any other energy form. The energy which is transported due to thermal exchange (heat energy) is of lower value (especially at low temperature) because it can be converted into kinetic energy only to a certain extent (Duit, 1984: 3).

Therefore, the crucial energy conceptions that are related to saving energy and generating power include conservation, transformation, and degradation. With the attempt to teach energy meaningful, a number science educators addressed science teaching should relate social situation and the public concern by using the STS perspective (Bybee, 1985; Fensham, 1988; Fleming, 1988; Hunt, 1988; Jegede, 1988; Nganunu, 1988; Solomon, 1988; Aikenhead, 1994b; Yager, 1996; Yutakom, 1999). However, there is no research in Thailand to study about concept of conservation, transformation, and degradation energy relevant to social situation and public concern.

The issues of energy saving, and controversies between generating power and pollution seems to be very involved for Thai people decision making in everyday life. The effort to teach energy concepts relevant students everyday life or social situation, should be started early as soon as possible. Thai science curriculum, the energy

concept was offered to learn for every level grade (IPST, 2002). However, this effort should start with students who have ability of learning in multidimensional way. According to the developmental view of learning, Grade 9 students (around 15 years old) begin to make sense for solving abstract problems and offering reasons in a multidimensional way (Bybee and Sund, 1982). This implies that Thai students at this level may understand energy as an abstract concept and social issues related to science and technology in a manner very similar to adults.

As about argument, to teach energy concept relevant students everyday life or social situation, this research could be carried out with Grade 9 students to teach concept of conservation, transformation, and degradation energy in the process of generating power by using STS approach.

3. Rationale for Using Science Technology Society (STS) Approach

The case for using the science-technology-society (STS) approach is because it might be meaningful and relevant to the students' experiences. This claim is reasonable when it is informed by learning theories and is consistent with the layman ideas of energy in Thailand.

3.1 Learning Theories

In the past, constructivism is concerned with constructing mental representations of certain structures or features of the world outside that are stored in the human brain. From the personal constructivist perspective, learning is seen as construction of mental models. Knowledge then is something an individual constructs (von Glasserfeld, 1993). However, learning science is seen to involve more than the individual making sense of personal experiences. It is also being initiated into the way of seeing which has been established and found to be fruitful by the scientific community. The social constructivist perspective claims that knowledge can be distributed among the members of a certain community or shared by the community.

Knowledge, then, is something that is between the individual and the social (Duit and Treagust, 2003).

The views of both personal and social constructivism should be taken into account for learning science, and both views should be considered in discussion of learning theories (Duit and Treagust, 2003). Social constructivist learning theories suggest that teaching science should be based on students' experience, and relevant their society and culture. This suggests that learning science could be shifted from personal construction by individual learners toward social construction (Hodson and Hodson, 1998) and learning viewed as a process of enculturation in which the aspirant members of a culture learn from their tutors or experts (Osborne, 1996). This argument suggests that learning is a form of cultural apprenticeship and that cognition is situated in specific contexts. This view was expanded from the learning theory of socio-cultural view (Dixon-Kraussm, 1996). With the important socio-cultural view, the researcher needs to consider the influence of different cultural attitudes toward energy learning in Thailand.

Teaching and learning energy could use the socio-cultural perspective that is concerned with the influence of cultures to interact in energy classroom (Billett, 1996). Brown, Collins and Duguid (1989) describe the basic ideas of situation related to constructing knowledge as a term of "situated cognition". Situated cognition means that cognitive processes differ according to the domain of thinking and the specifications of the task context (Coll et al. 2005). The term of situated cognition raises the question of the cultural influence on conceptual knowledge. Therefore, socio-cultural view means educating people for the futures, learning based on their societal and cultural values.

This suggests that situations of society influence for constructing energy knowledge. According to the argument of learning theories, the STS could carry out this because it offers science teaching that relates science concept, nature of science (energy) and technology, society, and social concern or cultural perspectives (Bybee, 1985; Jones, 2004).

3.2 Layman Ideas of Energy

Meaningful teaching and learning energy could be relevant to the social situation and the student's experience. The layman ideas of energy in Thailand involve the saving of energy and controversies about generating power (Watchamul, 1998). This suggests that surviving in everyday life in Thailand require people who have problem-solving and decision-making skills, and values that involve dealing with the interactions among science, technology, and society for local issues about energy.

To provide people, the goals of science education have already addressed requiring people who must understand science in level of multidimensional scientific and technological literacy in order to meet agreement about issues of science technology and society. The solution of controversies about energy may be provided through energy teaching and learning through STS approach because it helps to support teaching and learning energy relevant to social situations. The STS develops skills to use the processes of scientific and technological inquiry for information gathering, problem-solving, and decision-making; and to use values and ideas involved dealing with the interactions among science, technology, and society for local issues, public policies, and global problems (Bybee, 1985).

Consequently, energy as abstract concept (Duit, 1984) should be presented by STS because this provides students with a simplified perspective on the human and social aspects of science (Aikenhead, 1994a). Therefore, the STS courses could be generated from layman ideas of energy in order to give the concrete experience to students.

Clarifying the Research Problem

The educational reform emphasizes life-long learning. The learning can take place anywhere, at all time, and all levels within learners themselves and outside the classroom (ONEC, 2000a). Focus on many controversies about energy in Thailand;

people need to have skills of thinking, problem-solving, and decision-making; and values that involve dealing with the interactions among science, technology, and society for local issues about energy. This argument mainly involves meaningful teaching and learning of the law of energy conservation, energy forms and sources, energy transformation, and energy degradation in Thailand.

To provide people in the future, all students should have chances to learn energy that related to technology, and society for local issues about energy. Thai science curriculum, the energy concept was offered to learn for every level grade (IPST, 2002). Thailand compulsory education is stipulated until Grade 9 (ONEC, 200b). It seems to be good providing people in the future, if the energy teaching and leaning related to technology and society for local issues about energy will be provided during Grade 1 – 9. However, this effort should start with students who have ability of learning in multidimensional way. According to the developmental view of learning, Grade 9 students (around 15 years old) begin to make sense for solving abstract problems and offer reasons in a multidimensional way (Bybee and Sund, 1982). This implies that Thai students at this level may understand energy as an abstract concept and social issues related to science and technology in a manner very similar to adults.

Regarding the socio-cultural view, it provides idea of teaching and learning based on society and cultural values. The STS perspective offered teaching and science should relate science concept nature of science and technology, society, and social concern or cultural perspectives that might advocate meaningful teaching and learning. This raises the next questions.

- Can the STS approach advocate Grade 9 Thai students to meaningfully learn the concepts of the law of energy conservation, energy forms and sources, energy transformation, and energy degradation?
- How could the teachers teach these energy concepts through the STS approach?

As the socio-cultural view of learning, the different culture of learner and contexts should be taken into account for teaching and learning energy. This research will be carried out in Khon Kaen province, Thailand. The research is designed to be carried out in the different school contexts in Khon Kaen province including schools in the city, small town, and rural area.

Aims of the Research Study

The purpose of the research study was to enhance energy teaching and learning through STS approach in Thailand. The study was designed to achieve the following aims:

- To explore students' ideas about energy transformation, conservation and degradation; and these concepts relate to society and technology;
- To explore teachers' existing ideas of the concept of energy transformation, conservation and degradation; and perception of these concepts related to teaching and learning;
- To develop the STS energy unit and design the enhancing that is based on students' and teachers' existing ideas about energy concepts and energy teaching and learning;
- To reflect the trialling the energy teaching and learning through STS approach that consider the developing students' thinking skill, problem-solving, and decision-making; and values that involve dealing with the interactions among science, technology, and society for local issues about energy.

To achieve the aims of the enhancing energy teaching and learning through STS approach, the research questions addressed are specified next.

The Research Questions

Two sets of research questions were formulated for achieving the aims of study. The first explores (1) students' ideas about energy transformation,

conservation and degradation; and how these concepts relate to society and technology; (2) teachers' existing ideas of the concept of energy transformation, conservation and degradation; and perception of these concepts related to teaching and learning. The second set explores the process of teaching and learning conservation, transformation, and degradation energy that uses the STS approach for Grade 9 students in Thailand.

Research questions of the set one follow:

1. What are students' existing ideas about energy and energy related technological and societal issues; and how their existing ideas inform basis ideas for developing the STS energy unit?
2. What are the participating teachers' existing ideas about energy and energy teaching and learning; and how their ideas inform basis ideas for developing the program for enhancing the STS energy teaching?

Based on teachers and students' ideas, the energy unit is constructed, leading to the second set of research questions. The second set is the following lists:

3. How do students respond to teaching trial intervention of the STS energy unit; and what information resulting from intervention could be applied to enhance the STS energy teaching?
4. How does the researcher provide the participating teachers to teach energy through STS approach?
5. What are the affective and cognitive out comes, difficulties, and strengths for energy teaching through STS approach in the different three schools?

Delimitation of the Study

The use of the STS approach is relevant to a wide range of educational concerns and science, technology and society issues. The scope of this study was limited to explore the use of the STS approach to teach concepts of the law of energy

conservation, transformation, and degradation energy for Grade 9 students in Thailand. The research design was restricted to STS issues within energy and technology issues that influenced students' communities. The research sample was Grade 9 students in Khon Kaen, Thailand.

Anticipated Outcomes

This research clarified the enhancing energy teaching and learning through the STS approach in Thailand. Anticipated outcomes could be as below:

- To clarify process of the developing the STS energy unit;
- To obtain possible alternative strategies for the energy teaching and learning through the STS approach in Thailand;
- To give reflection how the STS energy teaching and learning in the different schools work; and
- To give information the science education stakeholder in Thailand that may take further applications of science teaching through the STS approach.

Summary of Chapter 1

The goal of science education aims students to think by considers the relationship between science, technology and society (IPST, 2002). The educational reform raised the crucial aspects of the learning that could take place anywhere, at all time, and all levels within learners themselves and outside the classroom (ONEC, 2000a). The controversies about energy in Thailand also raised the importance of providing people to solve these social problems concerning with the relationship between science, technology and society. To provide Thai people in the future, this research study aim to enhance Grade 9 energy teaching and learning through STS approach in Khon Kaen province, Thailand. The STS energy unit and program for enhancing energy teaching will be developed concerning with the students' and teachers' existing ideas about energy. Then, the outcomes of the energy teaching and learning through STS approach will be reflected considering with the developing students' thinking skills, problem-solving, and decision-making; and values that

involve dealing with the interactions among science, technology, and society for local issues about energy.

This study regards the socio-cultural view. To develop a theoretical framework of this study, chapter 2 reviews the literature including context of science learning in Thailand; teaching and learning about energy; learning theories; socio-cultural perspective influenced towards teaching and learning; learning energy in society and technology context; and energy teaching through science, technology, and society approach. Then, this research was conducted regarding the interpretive paradigm. The process of interpretation aims to interpret students' ideas about energy concepts, energy related technological and societal issues and what teachers' existing ideas of energy concepts and perception of energy teaching and learning are; and the reflection of teaching and learning energy related to issues of science, technology, and society. According to the process of interpretation, chapter 3 clarified the research design into three phase including exploration, intervention, and evaluation phase. Regarding these three phases, data analysis and interpretation is presented in chapter 4, 5, and 6. Chapter 4 reports exploring students' and teachers' existing ideas about energy, and discuss assumption of developing the STS energy unit and the program of enhancing energy teaching. Chapter 5 reports the developing of the initial trialling of the STS energy unit; and the results of the initial trialling that was trialled by the researcher in order to give implications for further trialling. Chapter 6 presents the outcomes of the enhancing the STS energy teaching and learning in three different schools. Finally, chapter 7 concludes with an overview of this research, and gives implications for further research.

CHAPTER II

LITERATURE REVIEW

The purpose of this chapter is to clarify the context related teaching and learning energy in Thailand. This context of learning suggests how to teach and learn meaningfully energy.

In this chapter reviewed the following areas of literature:

1. Context of learning science in Thailand
2. Teaching and learning about energy
3. Learning energy as informed by learning theories
4. Socio-cultural perspective influenced towards teaching and learning
5. Learning energy in society and technology context
6. Energy Teaching Through Science, Technology, and Society Approach

The main findings of the chapter are summarized at the end of the chapter, with focusing on how they inform meaningful learning and teaching energy in Thailand.

Context of Learning Science in Thailand

Science education in Thailand is influenced by the educational policy; Thai society; and the Thai world-view. Therefore, educational reform, Thai education system, and the goal of science education, are discussed below. This will be related to the context of teaching and learning energy in Thailand.

1. Educational Reform in Thailand

Thailand has had educational reform since 1997. This section discusses the rationale for the new wave of educational reform and how science educators and

teachers can accomplish the goal of reform. To provide a broader perspective, the history of educational reform will be discussed.

1.1 History of educational reform

The history of Thai education began in AD1292, after King Ramkhamhaeng, of the Sukhothai monarchy of Thai Kingdom, invented the Thai alphabet (MOE, 2004). The main Thai traditional education was provided by the Buddhist order (the Sangha). Education was offered in the temples, the King's palace and family settings. Children were offered non-formal learning of agriculture and social skills in the context of the extended family social norms. The temples provided for boys a broader framework of socialization and intellectual qualities highly valued by society. The aims of the monastic education were essentially ethical and religious, with literacy as a preparation for the monastic life. Girls were given no formal education, but were taught the arts of handicraft, weaving, sewing, cooking, and helping in the fields (ONEC, 1998b; Pitiyanuwat & Sujiva, 2000). The traditional Thai education continued to operate in this way for long time even when Thailand was ruled by many different monarchies – from the period of Sukhothai, Ayutthaya, Thonburi, and Bangkok (MOE, 2004). The turning point for modern education came when King Chulalongkorn, ruled Siam from 1868 – 1910. Since this time, there have been four major periods of educational reform in Thailand, including the new reform (ONEC, 1998b; Fry, 2002).

The first wave of Thailand educational reform was sparked in the King Chulalongkorn era (MOE, 2004) when Thailand was known as Siam. The major reform was the creation in Siam of a modern educational system with the capability to serve the entire kingdom. The public schooling was established across the kingdom (ONEC, 1998b; Pitiyanuwat & Sujiva, 2000).

The second educational reform occurred during the period 1972 – 1980 (Fry, 2002). Before 1973, Thailand government was run under the power of the military. They dominated Thai politics in an authoritarian manner. Government

decisions were made based on the leader rather than research (Taweessate & Nuensakul, 2000). The government policy was strongly top-down. In education, the curriculum had been rigid and restrictive. However, the science education institute- the Institute for the Promotion of Teaching Science and Technology (IPST), was established in 1972 (Soydthurum, 1990) during the period of authoritarian military government. This suggests that the Thai education reform had already begun, especially in science education.

The third wave of educational reform was evolved because of a concern with competition on the international stage. By the early 1990s, the Thai economy was becoming increasingly internationalized. Educational reform emphasized Thailand's need to adapt to the challenges of globalization and internationalization. The basic premise was that for Thailand to be internationally competitive (ONEC, 1999), it needed to improve its education system to prepare people for an increasingly international global era. Reflective of the commission's emphasis on Thailand's globalization and internationalization context, the international education institution has been seen to change dramatically. A number of international schools were established and, a number of courses in the university were offered as international instruction (Fry, 2002).

Finally, the new wave of Thailand's education reform was rising, influenced by the economic crisis, globalization, and lack of education quality (ONEC, 1998b). The following section will discuss the new educational reform.

1.2 The Matter of New Educational Reform

The new educational reform began officially when the Ministry of Education launched the National Education Act in 1999 (ONEC, 2000a: 5) which introduced effective education reform. The goal of Thai education reform is to realize the potential of Thai people to develop themselves for a better quality of life and to develop the nation for peaceful co-existence in the world community. The education

reform will be conducted in four areas including school reform; administrative reform; teacher reform; and curriculum, teaching and learning reform.

The first area of reform is school reform. Effort will be increased to standardize the quality of education in all levels and types of schools and educational institutions. The schools and educational institutions will be assessed for internal quality assurance once a year and external quality assurance at least once every five years (ONEC, 1999).

The second area, administration, has been decentralized to local organizations and educational institutions. Local administration organizations will have the right to provide education at all levels according to readiness, suitability and requirements of the local areas. But, in the new reform, the Ministry of Education will prescribe the criteria and procedure for assessing the readiness to provide education of the local administration organizations. In the past, administrative decisions were made depending only on the Ministry of Education (ONEC, 1999).

The third area is teacher reform. There is the long history of a teacher-centred approach and a centralised management and monitoring system in Thailand (ONEC, 1999). Therefore, Thai teacher reform aims to change pedagogic philosophy from teacher-centred to student-centred. Teachers need to become truly professional practitioners who have the capacity to identify the most appropriate strategy and design learning experiences for specific learning situations. However, many teachers in Thailand still do not appreciate the need for change. One of the many problems of Thailand educational reform is the problem of having teachers and school administrators as technicians and not professionals. As professionals, they could be expected to understand both the theoretical and the practical nature of theories (ADB, 2002: 10 – 12). Another problem is the quality of teacher. Sinarat reported (1999), there was general consensus amongst educators, parents and students about the quality of teacher regressing in recent years. As a solution of these problems, the teacher reforms suggested were (1) to develop new structural and functional requirements for organisation units concerned with improving teacher development; (2) to provide

guidelines for new teacher training programs both in-service and pre-service; and (3) to establish quality assurance mechanisms for teachers, including a licensing system for all teachers and teacher education institutions.

The pre-service teacher reform has concentrated on the development of two models. In the first model, a six year program, students will study for a basic degree such as a BSc. and follow that by a two year Graduate Diploma in Education, or MEd. The two years in Faculty of Education is made up of one year of teaching training and a year of professional classroom practice. The second model is a five year BEd. In this model, students have to study teaching training and a major subject area, such as physics, in the first four years. The fifth year is professional classroom practice.

In Thailand, the in-service teacher training has been conducted by the Ministry of Education and the IPST but there were a few training courses offered before emerging educational reform. A consequence of this is that, the majority of Thai teachers lack a clear understanding of the concepts, principles, and processes involved in the new approaches of teaching and learning (ADB, 2002). In the reform, teachers need competencies to implement new approaches of teaching and learning. Thai teachers need to have the capacity to provide the range of learning environments to suit the needs of the learners (ONEC, 2000a: 5). For example, teachers could invite local experts into classroom so that children can discuss issues and interact with them and learn from their experience and stories. This enhances to develop learning as grass roots. It is essential that the teachers are given more comprehensive training in theoretical, philosophical and practical aspects of new teaching and learning for appropriate specific learning situations (ADB, 2002: 22).

The fourth area is curriculum, teaching and learning reform. The new reform aims to decentralise curriculum construction, moving the responsibility for development from the Ministry of Education to the local schools. The teaching and learning emphasis is on a learner-centred approach and life-long learning (ONEC, 2000a).

The curriculum is school-based. The schools have flexibility to produce a local curriculum but it must be based on the content standard. The content standard is prescribed by the IPST for science content, and the Ministry of Education for the other contents (ONEC, 1999; ONEC, 2000b). To raise education quality, the Ministry of Education launched the policy to create activities for preparedness in the learner while developing curriculum of all types and levels based on the following major principles:

- (1) Creating a happy learning environment for the learners of all levels;
- (2) Organizing teaching and learning processes that require systematic thinking and emphasizing practice rather than rote learning;
- (3) Encouraging the learner to learn more from nature and the environment;
- (4) Ensuring that the learner uses the experience and knowledge gained from their family and community as part of teaching;
- (5) Determine basic learning standards or requirements of the learner while encouraging each school to develop and improve on the basic standards as appropriate;
- (6) Allowing the local community and population to participate in curriculum development and text book production in accordance with the needs of each locality (MOE, 1996).

The new system of education stresses lifelong learning. This includes classroom learning in schools, non-formal education for adults and a system of informal learning. Learning can take place anywhere, at all times, and all levels within learners themselves and outside the classroom. With the emphasis on lifelong learning, Thailand must provide learning resources (ONEC, 2002a). For science teaching and learning, learning resources include science text books; electronic media such as video, television, internet, and etc.; science laboratories; botanical gardens; geological gardens; libraries; the national parks; science museums; factories; local research institutes; and local experts and scientists (IPST, 2002: 170). Teaching and

learning will emphasise the utilization of local wisdom and knowledge, and diversity of learning approaches (Fry, 2002: 31).

Teaching and learning approaches are learner-centred. This approach has been identified as key concept of education reform (ADB, 2002: 14). Learner-centred education evolved out of the constructivist paradigm of learning. Thai learning reform is based on the philosophy of constructivism. The ONEC (2002a) gave the meaning of learner-centred approach as learning processes aimed at development of the person and the enrichment of their lives. Learners should be offered learning experiences to develop to their highest potential and in line with their aptitude, interests and needs. Learning activities should be organised with regard to individual differences. They should enable learners to be in touch and interact with their whole environment such as other people, nature and technology; and to apply learning methods to their daily life (ONEC, 2002a: 26 - 27).

2 Science Education in Thailand

The science education in Thailand outlined the structure of curriculum that was reorganized after recently reforming of Thai education. Then, the section explained what crucial view of goal and vision of Thai science education, and finally, the energy curriculum for level of age Grade 7 – 9 would be discussed.

2.1 Structure of Curriculum

According to Thailand educational reform, the Ministry of Education launched the National Education Act in 1999 (ONEC, 2000a: 5) Thai education system comprises of 4 levels. They are pre-school, primary, secondary, higher education. The basic education shall be twelve years core curriculum with 4 grades level including lower primary education Grade 1 – 3 (7 - 9 years), upper primary education Grade 4 – 6 (10 – 12 years, lower secondary education Grade 7 – 9 (13 – 15 years), and upper secondary education Grade 10 – 12 (16 -18 years). Each grade level has the same goals and objectives with difference emphasis, and the same of

substance. The substance consists of body knowledge, skills or learning processes, values or virtues, morality and right behaviour. This substance is assembled into 8 subject groups of learning processes including (1) Thai language; (2) Mathematics; (3) Science; (4) Social studies, religion and culture; (5) Health and physical education; (6) Art; (7) Career and technology; (8) Foreign languages (MOE, 2002).

The science subject group consists of eight science content standards including (1) Living things and their survival, (2) Life and environment, (3) Matter and its properties, (4) Force and motion, (5) Energy, (6) Earth science, (7) Space and astronomy, and (8) Nature of science and technology. The science content standard is criteria that all Thai students must achieve. Each science content standard will be taught in every grades level (IPST, 1999). However, new curriculum is a school-based curriculum. Schools were empowered to construct their curriculum based on the national goal of science, vision of science learning, and content standard.

2.2 Goal and Vision of Science Education

According to the National Education Act (NEA) 1999; the goal of science education and vision of Thai science learning emphasise with the relationship between science, technology and society.

The goal of Thai science education aims students to think by considers the relationship between science technology and society. This goal need people who must understand science in level of multidimensional scientific and technological literacy in order to meet agreement about issues of science technology and society that affect the living across the world. The Thai science content standard has seven goals. Four of them relate to the relationship between science, technology and society. These four goals of science instruction are:

- To understand laws and principles of fundamental science;
- To realize interplay between science, technology, human kind and environment;

- To apply understanding about science and technology for use and survival in society;
- To acquire the characteristics of the scientific habit of mind, ethic, merit, and value for use of the creative knowledge of science and technology (IPST, 2002: 5).

Vision of science learning for Thai students included an awareness of interplay science, technology and society. Science learning is life long learning. So, the science classroom emphasise teaching and learning in real life and using local information. Students can learn science in multidimensionality views, study natural phenomena, and scientific issues in society. They can learn to administrate sustainable natural resources.

The goal and vision of Thai science education suggested science teaching and learning to emphasise with the relationship between science, technology and society; and life long learning. The energy is science conception that related everyday life. Energy, therefore, is learned to related social issues such as energy requirement, environment, and so on (Hobson, A. 1982). Energy in Thai curriculum will be discussed next.

2.3 Energy in Thailand Science Curriculum

For the new curriculum (1999), teaching and learning science is increasingly important because students have studied science starting at Grade 1 (7 years old) (IPST, 2002). This is challenge for teacher how to teach science for young children. Especially, Energy as abstract concept (Duit, 1984) will be taught also starting at Grade 1.

To obtain goal of Thai science education, this study aim to develop energy teaching and learning related technological and societal issues that may enhance student perceptions of the relationship between science, technology and society. With the reason of theory of developmental development, children (11 years old on ward)

in the formal operational stage have the ability to reason in the abstract without having to rely on concrete objects or events. The child's thinking increasingly resembles that of the adult (Birch, 1997: 68 -73). As aim to start energy learning related technological and societal issues, the age level of Grade 7 – 9 (around 12 -15 years old) is appropriate time to start. The quality of science learner is the desirable goals of science students. The quality of science learner (age level of Grade 7 – 9) also focuses on a view of the interplay between science technology and society. The qualities of Thai science learner after finishing Grade 9 that relevant interplay between science technology and society consists of:

- To understand the relationship between science and technology, and develop technological influence on quality of life and environment;
- To communicate (e.g. writing, talking, exhibiting, or using information technology) his or her scientific knowledge in public;
- To employ scientific knowledge and scientific process for surviving in real life and investigating scientific knowledge, and making supplementary investigations (e.g. science projects, or interesting tasks)
- To realise the value of scientific and technological knowledge in everyday life and work;
- To appreciate to use and take care of sustainable natural resources and the environment in his or her local area;
- To be able to work creatively and negotiate agreement in a group.

This research, focused on the achievement of the Grade 9 content standard that consists of:

- Students experiment and describe work, gravitational and kinetic energy, energy conservation, and its application;
- Students can investigate and compute electric energy and costs in using electrical devices;
- Students can select and use electrical devices (IPST, 2002).

As a school-based curriculum, teachers must construct their own energy curriculum to be appropriate in their local context of school. This study aims to develop energy teaching and learning related technological and societal issues. The energy issues in Thailand were energy saving and construction of power plant (Watchamul, 1998). To link these energy issues and energy conception together; students' alternative frameworks and scientific conception of energy conservation, transformation, and degradation need to be discussed next.

Teaching and Learning about Energy

The section is clarified students' alternative energy frameworks, and the layman ideas of the law of energy conservation, energy transformation, and degradation in order to give implications for the energy teaching and learning. Each aspect is discussed below.

1. Students' Alternative Energy Frameworks

In the scientific view, the concept of energy involves the four basic aspects; conservation, transformation, transfer, and degradation. Energy transfer is viewed as a flow of energy which can be transferred from one system to another (from one place to another) (Duit, 1984; Duit & Haeussler, 1994). Energy transformation involves the concept of converted from one form to another. Energy conservation is the concept that the total energy of an isolated system always stays the same, regardless of any processes occurring within the system (Hobson, 1982; Duit, 1984). Energy degradation is the simple concept of entropy that looks at the second thermodynamic from the atomic point of view (Hobson, 1982; Duit & Haeussler, 1994). However, many textbooks give a short definition of energy as a precondition or ability for doing work (Duit, 1984). Duit and Haeussler (1994) claimed that the conception of energy that 'Energy is the ability to perform work' should be banned and rather, students should be introduced to the four concepts of transfer, transformation, conservation, degradation (Duit, 1984). They argued using a number of reasons:

First, the conceptualization may mislead students to think that energy is the cause of processes. Secondly, the idea about the ability to perform work is in danger of reducing the energy concept to mechanics or at least to neglect that energy is the unifying concept that allows us to bring aspects of many areas of science together. Thirdly, the conceptualization leads to difficulties in understanding the second law of thermodynamics appropriately. If energy is seen as the ability to perform work and if this ability decreases in every process then there is a certain contradiction to the principle of energy conservation (Duit & Haeussler, 1994: 188).

The student's existing ideas about energy are different from the scientific world-view. Many western research studies indicated that conceptions both before and after energy teaching mainly reflect the use of energy in students' life-world domain; this is especially so where an energy concept is in use that differs from the science energy concept (Duit & Haeussler, 1994).

Watts (1983) studied views of sixth form students in London. He explored students' ideas by using the interviews about instances (IAI) approach. His analysis listed seven alternative frameworks including (1) human centred energy, (2) a depository model of energy or as a product, (3) energy as an ingredient or as product, (4) energy as obvious activity, (5) energy as product, (6) energy is functional, and (7) energy as some kind of fluid - a flow-transfer model of energy.

And, there were other studies, similar Watts's (1983). Studies in the English language context; Watts and Gilbert (1983), Solomon (1983a, b, & c), and Brook and Diver (1984), Bliss and Ogborn (1985), Gair and Stancliffe (1988); have generally resulted in considerable percentage of human-centred ideas of energy and of associations with food.

There were also interesting students' ideas from different countries. Findings from Germany (Duit, 1981) have shown that the framework of human-centred energy is very infrequent. Finding from Israel (Trumper, 1990a) and the Netherlands (Lijnse, 1990) have commonly shown a high percentage of the fuel idea of energy.

Findings from Thailand (Sengsook, 1997) have also commonly shown high percentage of the fuel idea of energy. Sengsook (1997) investigated Grades 7 – 12 Thai students' conception of energy by using IAI. She classified twelve student frameworks:

- (1) Energy is associated with human beings;
- (2) Some objects have energy and expand it;
- (3) Energy is a dormant ingredient within objects and is released by a trigger;
- (4) Energy is an obvious activity;
- (5) Energy is a by – product of a situation;
- (6) Energy is fuel and functional;
- (8) Energy could be transferred from one system to another;
- (9) Energy could be converted from one form to another and students could name its form correctly;
- (10) Energy could be converted from one form to another but students could not name its form correctly;
- (11) Energy is concerned with force, power or other qualities of objects;
- (12) The natural things do not have energy.

Student's alternative concepts about energy stem from a context which is inappropriate for school science, but which is valid and valuable in their everyday world (Trumper, 1990a). Students' alternative frameworks of energy in different countries and cultures showed their idea of energy related to their experience of society.

From a constructivist perspective, the teacher should investigate students' prior knowledge and develop ways which incorporate these viewpoints within teaching (Trumper, 1990a; Duit & Haeussler, 1994). According to Sengsook's (1997) findings, teaching and learning energy in Thailand should be concerned with frameworks of the fuel idea of energy that is student's misunderstanding of energy concept as energy resource.

For meaningful teaching and learning about energy, the basic concept of energy should be teach the relevance of energy to understanding occurrences in students' life-worlds, most notably to understanding energy issues in society (STS issues) and to acting in energy-concerned ways (Duit & Haeussler, 1994). The STS issues of energy in Thailand involve saving energy and generating power, so the basic concept of energy relating to these issues are conservation, transformation, and degradation. The next section will discuss how these concepts relate to the student world view and public concern; and their relationship.

2. Conservation, Transformation, and Degradation Energy

The energy in the mass media is related to saving energy and generating power. These correspond to the concepts of conservation, transformation and degradation. However, the popular understanding of these concepts is very different from the scientific concepts, and the contrasting views will be examined in the next section.

In the scientific view, energy transformation involves the concept that energy can occur in several forms; and it can be converted from one form to another (Duit, 1984). Energy conservation is the concept that the total energy of an isolated system always stays the same, regardless of any processes occurring within the system. When energy is transferred from one system to another, or when energy is transformed from one form to another, the amount of energy does not change (Hobson, 1982; Duit, 1984). Energy degradation is the simple concept of entropy (Duit & Haeussler, 1994). Entropy is energy concept that looks at the second thermodynamic from the atomic point of view. Using the concepts of thermal energy and temperature, entropy is given the meaning of the concept of disorganization. The disorganization in the isolated systems can easily become more disorganized, but those systems can become more organized only with outside assistance (Hobson, 1982). As the simple concept of entropy, therefore, the concept of degradation energy involves the processes taking place in closed systems where the amount of energy

does not change; but the usefulness of energy inevitably declines and is hard to reverse to become more useful energy (Duit & Haeussler, 1994).

The process of generating power involves these three energy conceptions. For example, the steam-electric power plant involves the concept of energy transformation when the thermal energy is transformed into electrical energy, but there is a partial transformation of thermal energy into other forms such as waste heat. As the simple concept of entropy, or the Second Law of Thermodynamics, energy degradation provides some fundamental reasons for the fact that their efficiencies are less than 100%. The energy conservation means that the amount of thermal energy input lost equals the amount of electrical energy output and other forms of energy that occur in the process of generating power (Hobson, 1982).

But, in the scientific view, there is no concept of saving energy. However, energy degradation relates to saving energy because it can show why people need to save energy (Duit & Haeussler, 1994), and why there is an energy crisis (Hobson, 1982). Because the concept of energy degradation is involved in the processes the total energy is conserved. Although the amount of energy has not changed, the 'useful value' of the energy has decreased. The different forms in which energy occur have different useful values. For instance:

The energy of a moving body (kinetic energy) and the energy transported while current is flowing (electrical energy), for instance, are of high value. It is possible to convert them - in principle - totally into any other energy form. The energy which is transported due to thermal exchange (heat energy) is of lower value (especially at low temperature) because it can be converted to other kinetic energy only to a certain extent (Duit, 1984: 3).

With the layman ideas of energy, it can be assumed that there is a gap between the student world view and scientific view about conservation, transformation, and degradation of energy. In the western view, students seem to understand conservation energy as saving energy (Duit, 1984; Solomon, 1985; Carr & Kirkwood, 1988;

Trumper, 1990a). The student confusion of saving energy in everyday terms and energy conservation in scientific terms also occurred in Thailand (Yuenyong et. al., 2005). This confusion might be generated readily socialized understandable, for example, the government campaigned for saving energy as the Project Energy Divide By Two, that the terms saving and conservation are interchangeable in common usage. To eliminate this misunderstanding, Solomon proposed that teachers should simply teach about the dissipation and degradation of energy before conservation instruction (Duit, 1984; Solomon, 1985). Solomon (1985) and Duit (1983) suggested that energy degradation may be a helpful entry point to teaching and learning the conservation of energy. The stress on energy conservation in the sense of ‘saving energy’ prevalent in other subject areas as well as science, provides a strong alternative meaning which is closer to the student’s world than the more sterile, scientific view. The common Thai physics lesson, which associates the concept of conservation of energy with balls rolling up and down parabolic curves, has little relevance to everyday life.

Some students misunderstanding comes from textbook definitions and teacher expressions that never provide a clear concept of energy degradation. Letherman (1973) looked up the definition of energy and found that eight of twelve high school physics textbook presented a very short definition of mechanics processes as: “energy is the ability (or capacity) to do work”. Students have difficulty learning energy conservation because they are limited by the definition of energy as mechanical processes (Watts, 1983; Duit, 1984). However, at the same time, students learn about the work done against friction which produces thermal energy or heat. The Second Law of Thermodynamics shows it is not true that the thermal energy of a system is equal to its capacity to do work (Trumper, 1990b). This seems to be assumed as similar in Thailand even though there is no research because of the definition of energy in Thai text book is also given as mechanical processes (IPST, 1990). Therefore, lessons on energy conservation in Thailand should also spend time to introduce energy degradation.

Besides eliminating student's misunderstanding of conservation energy, there are other reasons to include energy degradation in the basic aspects of the energy concept. Duit and Haeussler (1994) provide three reasons: energy and entropy are closely related other disciplines; conservation needs to be understood as part of that relationship; degradation is a key in the STS approach.

Firstly, energy and entropy are closely related to one another in science instruction, the main emphasis has been placed on energy and the conservation aspect (Duit & Haeussler, 1994). For example, the entropy relates to life. Entropy describes changing process of life.

Planet earth itself has become more organized during the past few billion years, the period during which life evolved. According to the Second Principle of Thermodynamics; outside help was needed to do the job. The outside help came, obviously, from the sun. Turn off the sun, and the Earth will soon become highly disorganized. ... You can maintain yourself in this highly organized, low-entropy state only by being in constant interaction with your environment. Take away the air, the water, and the food in your environment and you will soon run down. Your body will eventually return to the disorganized dust of Earth ... (Hobson, 1982: 185).

Secondly, the conservation idea will become understandable for students only if the degradation aspect is also given attention. In all processes that take place in reality, there is the previously mentioned interplay of conservation and degradation. Hence, real processes are only understandable for students if both aspects are used to explain them.

Thirdly, the degradation aspect is a key issue in STS approaches, that is, in attempts to make students familiar with the energy problems of society (Duit & Haeussler, 1994).

As discussed above, the concepts of energy conservation, transformation, degradation support to each other for easily making sense to students. Energy

degradation helps student to more easily understand energy conservation because it provides an answer to why there is less output as electrical energy in process of generating power than the input as potential, mechanical, or thermal energy. The concept of energy conservation helps to explain more about the energy transformation. For example, electric energy is used when mixing orange juice in a blender. Where does this energy go? It must go into warming the juice. A lot of it goes into warming the motor, also, as evidenced by the heat of the blender near the motor. The laws of energy conservation state that the amount of electric energy lost equals the amount of kinetic energy and thermal energy gained (Hobson, 1982).

The perspective of the relationships between conservation, transformation, degradation energy; together with student ideas and public concern about these concepts, gives an insight into a meaningful way of teaching and learning energy. The next section will discuss a possible way to teach energy beginning from the student world view and public concern in Thailand.

Learning Energy as Informed by Learning Theories

Learning theories can suggest how teacher should provide for their students. This section discussed somewhat should be recognized as informed by learning. Firstly, the different views of learning theories were offered including behaviourist, cognitive development, personal constructivism, social constructivist view, and socio-cultural view. Then, the applying for learning energy was discussed.

1. Behaviourist View

The Behaviourist view arises out of a relatively long history of thought and investigation. There are several typical models of learning. Such models have been upon the conditioned response, trial and error, insight, and reinforcement model. Thorndike (1898) described learning as trial and error. He tried to understand the learning of animals by performing experiments. A hungry animal was placed in a box with slatted sides and a door that could be opened by pressing a wooden lever to

release a latch, allowing the animal to reach food placed within his view outside the box. In the model of conditioned response, Pavlov (1927) viewed learning as a matter of establishing conditioned response. Pavlov's studies of conditioning in dogs found that learning occurred when the buzzer was presented together with the food in a number of trials. In the model of conditioned insight, Kohler (1929) used a variety of problem situations to study insightful learning in chimpanzees. Skinner (1968) employed Thorndike's experiment to describe the learning situation of rat pressing a lever by using the term reinforcement. Reinforcement is the name of a particular arrangement of stimulus and response conditions that bring about the learning of new associations (Gagne, 1977: 7 – 15). These models were established in the use of animals for experiments on learning. However, educators have brought this view into the classroom for describing teaching and learning.

In the behavioural approach, teaching is concerned with observable behaviour. What goes on in the mind of the students can not be observed and hence is of no consequence (Wheldall & Merrett, 1984). A learning occurrence, then, takes place when the stimulus situation, together with the content of memory, affect the learner in such a way that their performance changes from a time before being in that situation to a time after being in it. The change in performances is what leads to the conclusion that learning has occurred. In other words, learning involves changed behaviour and the only way to know that learning has taken place is to look for a change in the learner's behaviour. (Gagne, 1977: 3 – 5; Wheldall & Merrett, 1984).

In the behaviourist view, the learning occurs when the learner changes consequent behaviour of a capability. The learning hierarchy is a central concept of learning for the behaviourist psychological learning. Therefore, instruction should be sequenced, that means to teach the prerequisite ideas before introducing new ideas (Gagne, 1970: 237 -240).

Behaviourism provides a narrow view of learning although most curricula are still written in behaviourist terms (Jones, Bell, and Carr, 1995; von Glaserfeld, 1992). Behaviourist instruction is considered more appropriate to the teaching of observable

skills rather than to the teaching of any material which has significant conceptual component, since it takes no account of the conceptual framework the learner brings to the situation (Driver, 1982: 73). For facilitating conceptual understanding, the teaching process is required to focus beyond the observable behaviour of learners and attempt to understand the cognitive process associated with learning.

2. Cognitive Development view

The theory of cognition was proposed by Piaget (Lefrancois, 1994). Cognition is considered developmental in that it imposes age-related restrictions on what a child can learn, and viewed human development as occurring in terms of age-defined stages (Lovell, 1980). Piaget has identified four different stages of cognitive development.

Piaget's stage theory argues that there is a development of general thinking skills. There are four kinds of logical operations that children exhibit in sequence: sensorimotor, pre-operational, concrete operational and formal operational (Duit & Treagust, 2003: 9). He proposed that the child moves through each of these stages in turn, in a predictable sequence within a predictable age range.

According to the stage of formal operation, Grade 9 students (15 years) have a fully developed cognitive structure. They can solve abstract problems and give reasons in multidimensional way. This implies that learners at these levels will make sense of social issues related to science and technology in a manner very similar to adults. However, some research has shown that the kind of abstract thinking described by Piaget as occurring at the formal operational stage is not attained by all teenagers or adults. A study by Lewis (1981) showed that only 50 – 60 percent of 17 year-olds used formal operational logic in problem-solving tasks (Birch, 1997: 77).

Piaget's work on human cognition informed modern understandings of the human psychology, and has been expanded how individuals construct their own

knowledge. This expansion became learning view of personal constructivist that will be discussed in next section.

3. Personal Constructivism View

Constructivist psychology is based on the view that knowledge is a human construction (von Glasserfeld, 1992; Driver, 1993). Piaget's view is considered as a constructivist because he argues that learners actively participate in the process of construction of meaning. Radical or personal constructivism regards knowledge as being in the head of individual who constructs what they know on the basis of their own experience (von Glasserfeld, 1995: 1).

Personal constructivists regard learning as a private activity and the process of construction of meaning is projected as occurring purely at a personal level (von Glasserfeld, 1992). A major focus is given to the experiences, ideas and knowledge about phenomena that the learner brings to the classroom; these ideas may either help or hinder the process of learning (Freyberg & Osborne, 1985). However, constructivists impose no developmental restrictions on learning (Driver, 1982). Piaget argued that the acquisition of knowledge was 'adaptive'. Adaptation in the cognitive domain is not the same as the physiological adaptation of biological organisms. On the level of cognition, it was not a straightforward matter of survival of extinction, but rather that of conceptual equilibration. Learning is changed into a higher form of adaptation.

In mechanism of equilibration, Piaget is looking for mental and not biological process (von Glasserfeld, 1995: 55). He described the process of learning by analogy as ideas of assimilation, accommodation and equilibration. Assimilation is the process of the individual's adaptation to new sense impressions, with the inputs basically fitting the already-existing cognitive structure. Accommodation is the characteristics that were disregarded by assimilation. If the unexpected outcome of the activity was disappointing, the newly noticed characteristics may effect a change in the recognition pattern and thus in the conditions that will trigger the activity in the

future. Alternatively, if the unexpected outcome was pleasant or interesting, a new recognition pattern may be formed to include the new characteristics, and this will constitute a new scheme. In other words, accommodation indicates that restructuring of the already-existing structure is necessary when the inputs do not fit existing cognitive structure. Assimilation and accommodation are always intimately interrelated; there is no assimilation without accommodation and vice versa. Learning takes place when a scheme leads to perturbation. If the inputs do not fit, there is a disturbance of the mental balance or a cognitive conflict. The balance can be restored by a process of equilibration, that is, by an interplay of assimilation and accommodation (von Glasserfeld, 1995: 62 – 68; Duit & Treagust, 2003: 9).

Personal constructivism epistemology is a deliberate and public attempt to move away from traditional epistemology. Thus, many personal constructivist writings seem to be a desire to escape notions of “absolute truth,” which are accurate or even partial representations of the real world (Osborne, 1996). For instance, von Glaserfeld (1993) argued that personal constructivism is post epistemological and an attempt to cut loose from the philosophical tradition that knowledge has to be a representation of reality. Instead, truth is replaced by the notion of viability. Fundamentally for von Glasserfeld, knowledge is always the result of an active construction and therefore cannot be transferred to a passive receiver (von Glasserfeld, 1995). Thus knowledge exists only in mind of cognizing beings, where it is constructed, and is not to be found, for instance, in books, texts, or other traditional repositories of human knowledge which simply represent symbols open to a range of interpretation. There is no knowledge without a knower. Tobin suggests that “We construct a model of gravity that is viable in that the model fits experience, but no matter how elegant, that model cannot claim to be an absolute truth” (Tobin & Tippins, 1993: 2). According their epistemology, knowledge is viable because of its coherence with other understandings and its fit with experience.

Basic to personal constructivism are the views that the individual makes sense of experience in order to satisfy an essential need to gain predictability and control over their environment (Confrey, 1993: 4). Learner will construct knowledge in their

own mind as model that is viable and fit their experience (von Glasserfeld, 1993; Tobin & Tippins, 1993). View of personal constructivist foster students' experiences inherent in solving a problem seen and chosen as one's own (Freyberg & Osborne, 1985; von Glasserfeld, 1993); and promote notion of discovery learning (Driver, 1993) and hence role of teacher in the teaching and learning process.

However, there are problems in one aspect of knowledge of personal constructivism. It fails to elaborate any criteria that determine the concept of "viability". How is the child to judge that the scientist's description is more viable? How is the child to know that there are entities for which we have well-established arguments for their existence and reliable theories that have better explanatory power than those of common sense reasoning? Constructivism singularly fails to elaborate any mechanism by which one theory can be considered more "viable" than another (Osborne, 1996). Tobin & Tippins (1993) argued that knowledge must be viable not only personally, but also in the social contexts in which actions do occur. Viability is therefore determined with respect to those actions which facilitate the attainment of goals in the social contexts of action. This argument extends the notion that ideas must be personally viable to encompass the idea that they must be viable within a social context. Thus, science becomes a set of meanings and concepts which evolve from socially negotiated understandings and not from a process of examining whether such inventions are supported when tested against the real world (Osborne, 1996). An alternative view (Shotter, 1992) is to picture learning as a socially constructed and linguistically sustained process that gives the teacher a larger role in teaching and learning process. In order to extend view of learning and elaborate the concept of viability, the social constructivist view will be discussion in next section.

4. Social Constructivist View

Social constructivists view the process of understanding and knowledge as being socially and actively constructed and influenced by the values and knowledge structures shared by society (Tobin, 1990; Driver, 1993). The potential of the social constructivist views of knowledge becomes obvious as being distributed and shared

rather than being the property of individuals (Duit & Tregust, 2003: 18). Scientific understandings are constructed when individuals engage socially and actively in talk about shared problems or tasks (Driver, 1993: 70; Duit & Tregust, 2003: 19). They are continuously being refined to improve social agreement (Bingle & Gaskell, 1994).

Social constructivist regards that children construct their own knowledge through social interaction – the social plane. Vygotsky described the process of learning as including the social context of cognitive development and the role of language in the development of higher cognitive functions (Hodson & Hodson, 1998). Any function in child development appears on two planes – social plane and psychological plane. The learning occurs when children interact in the social plane and then internalize into psychological plane. According to Vygotsky view, learning process occurs in the region of the zone of proximal development (ZPD) (Vygotsky, 1978: 85; Berk and Winsler, 1995: 20; Hodson and Hodson, 1998).

The zone of proximal development (ZPD) is “the area between the child’s actual developmental level as determined by independent problem solving, and the potential developmental level which could be achieved with the help of adults or more experienced peers” (Vygotsky, 1978: 86). That is learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers (Király, 2000: 40). The children learn external knowledge by interaction with others such as parents, teachers, or peers. After children internalize external knowledge, this knowledge is converted into a form of consciousness in psychological plane by scaffolding of adults or more experienced peers. The consciousness will be used as a tool for controlling their new conceptual system (Dixon-Krauss, L., 1996; Hodson & Hodson, 1998).

A fundamental of social constructivist is process of knowledge construction through social interaction. During interaction, learners need time to experience, reflect on their experiences in relation to their existing knowledge and resolve any perturbations that arise. They also need time to clarify elaborate, describe, compare,

negotiate, and reach consensuses on what specific experiences mean to them. This learning process must occur within the bodies of individuals (Tobin, 1990). Transferring of cognition from the social to the individual uses the “tool of mind”, or signs, to mediate relations between people. The signs, language, mediate the individual’s psychological processes. Mediation through sign, signs as language, is socially generated not biologically given or individually constructed. The role of language is, first as the vehicle of communication between people and then as the central means of communication with the self, then back to the socially shared and situated nature of cognition. Internalization of signs is the process of formation of higher mental functions through signs exchanged between people (Berk & Winsler, 1995: 20). This interaction can result in a discourse that helps a person to be clear about what they mean and can assist the process of establishing whether or not understandings are viable (Tobin, 1990: 31).

Teaching and learning interaction within ZPD is scaffolding for a building under construction. The child is viewed as a building actively constructing him or herself. The social environment is the necessary scaffold that allows the child to move forward and continue to build new competencies (Berk & Winsler, 1995: 20). In social constructivist approaches that have been employed in science education, the idea of situated cognition usually plays a key role (Duit & Tregust, 2003: 18). Situating learning means leaving the event that is to be studied within an authentic situational environment. As learning, from a constructivist perspective, is always directly related to the situation in which that learning occurs, the complexity of situation must be retained (Kiraly, 2000: 43).

Conclusion, social constructivist describes learning process that is knowledge construction through social interaction. According to Vygotsky view, learning occurs within ZPD that experts scaffold children to develop higher mental function. Within ZPD, children will internalize what they interact with expert as their own understandings. Internalization involves use signs or culture tool, such as language, in the process of formation of higher mental functions through signs exchanged between people. The signs, language, mediate the individual’s psychological

processes. Mediation through sign, signs as language, is socially generated not biologically given or individually constructed. With the process of social interaction and internalization through mediated sign, children could construct their own understandings that are viable that fit their own experience.

The social constructivist perspective portrays science education as a process of enculturation in which the aspirant members of a culture learn from their tutors and that novices are introduced to a community of knowledge through discourse in the context of relevant task. This argument presents that learning is a form of cultural apprenticeship and that cognition is situated in specific contexts, that is learning cannot be separated from context of learning (Osborne, 1996). This view of social constructivist was expanded new view of learning theory as socio-cultural (Dixon-Kraussm, 1996) that will be discussed next section.

5. Socio-cultural View

The socio-cultural approach rooted ideas from Soviet psychologist Vygotsky. Sociocultural perspective deals with the social and cultural origins of development (Dixon-Kraussm, 1996). This idea might be stated that it elaborates the view of social constructivist that is influenced of culture on the generation of knowledge and learning. The concept of culture is social behaviour and artefacts, description of the values, norms, and beliefs of a society (Cusick, 1987).

According to Vygotsky's view, the development of higher forms of mental processes in children occurs through their enculturation into society, through their education (Dixon-Kraussm, 1996). Wertsch and Toma (1995) concluded Vygotsky's writing that consists of three general themes: "(a) the use of a genetic (developmental method); (b) the claim that essential aspects of mental functioning in the individual derive from social life; and (c) the claim that a key to understanding human action, both on the social and individual planes, is understanding the tools and signs that mediate it (p: 160)". According to Wertsch (1985), Vygotsky's view was that there are two developmental strands: the natural one is elementary form that exists as

organic; and the cultural one is higher mental function such as memory, attention, perception and thinking. The natural strand as dominant early transform into cultural strand (Wertsch, 1985). This point illustrates social knowledge construction that brings the knowledge and ideas of individuals to contribute to a broader understanding among a group of people (Dixon-Kraussm, 1996). This Vygotsky's perspective of transition suggested that socio-cultural influences becomes of primary importance (Confrey, 1995).

With the socio-cultural perspective, the researchers should recognise the relationship between human mental functioning; and cultural, historical, and institutional setting (Wertsch, Del Rio, and Alvarez, 1995). To address the socio-cultural approach in to teaching and learning science, as view of Vygotsky, the construction of knowledge requires tool as mediated action (Wertsch, 1991). The mediation is understood as cultural tools that provide the link between the concrete action carried out by individuals and groups; and cultural, institutional, and historical setting (Wertsch, 1995). To observe how the 'mediation' is employed within socio-cultural activities; Rogoff (1995) suggested that observing should engage in the developmental processes with three plans of analysis as (1) apprenticeship, (2) guided participation, and (3) participatory appropriation.

The metaphor of apprenticeship involves active individual participating with others in culturally activity. The culturally activity has purpose to develop the less experience people becoming the mature participation in the activity. The apprenticeship metaphor has at times been used to focus on expert-novice dwellers (Rogoff, 1995: 142 – 143). Apprenticeship involves learning to use tools through participation in particular community and adoption of its culture (Brown, Collins, and Duguid, 1989; Rogoff, 1995).

Conclusion, the socio-cultural view expanded from social constructivist by elaborating of focusing on influenced of culture toward construction of knowledge that occurs in the process of social interaction. With socio-cultural view, students must construct their own knowledge that occurs while students interact with people

and situations in socio-cultural activities. To be clear how situations influence the construction of knowledge, this question should reconcile the aspect of cognitive and socio-cultural theories (Billett, 1996). The aspects of mental functioning can be understood by considering the social contexts in which they are embedded (Wertsch and Toma, 1995). Therefore, learning involves development of higher mental function through cultural tools in order to link between concrete actions that holding by individual and groups; and cultural institutional and historical cultural activities (Wertsch, 1995). Learning occurs while students interact through cultural tools as mediated action of developmental process within three plans of apprenticeship, guided participation, and participatory appropriation (Rogoff, 1995). This process offer view of participating or observing an expert practitioner's working that it might be helpful students' learning (Brown et al, 1989). In this manner, learning views as situated within community of practice (Lave & Wenger, 1991). Learning involves the process which the increasing participation of new comers in going practice shapes their gradual transformation into old timers (Lave, 1991).

A fundamental claim of socio-cultural approach is that mental functioning is assumed to be inherently situated with regard to cultural, historical, and institutional contexts. Learning involves not only constructing knowledge, not only becoming a member of a community, but also taking a stand on the culture of one's community (Packer & Goicoechea, 2000). This learning perspective suggests teaching and learning to focuses on issues how the thinking of students indifferent cultures and countries; how learn science today differ from 50 years ago (Wertsch & Toma, 1995).

The various view of learning theories suggests the researcher that how describe student's learning and how apply view of learning for teaching energy. Next section will discuss how to apply learning theories for learning and teaching energy.

6. Applying Learning Theories to Learning Energy

Science learning tends to be an inclusive view of learning theories which brings together approaches of different theoretical orientation (Duit & Treagust, 2003). Each learning theory is helpful in teaching and learning energy.

The view of observable behaviour provides basic information for interpreting when students show evidence of learning. This should be taken into account in science instruction. In other words, intellectual skills, cognitive strategies, motor skills and attitude should be recognized in teaching and learning science because skills of remembering, thinking, clarifying are the basic skills of learning. Alternately, Gagne's (1970) learning hierarchy suggests that learning should begin as concrete then turn into abstract concept. Students must acquire science concepts and skills before learning applications of science. This aspect is insight learning and teaching of energy. Learning energy as an abstract concept (Duit, 1983) should begin in concrete ways, such as the aspect of using energy in everyday life.

As the aim of this research, teaching and learning energy will enhance students' ability of scientific and technological literacy (STL). With concerning on ability of STL, students have to learn science in multidimensional way that has to make connections between science and technology; and larger issues of social challenge (Bybee, 1997). According to learning theory of cognitive development, the stage of formal operation suggests that Grade 9 students (15 years) have a fully developed cognitive structure. They can solve abstract problems and give reasons in a multidimensional way. This implies that learners at these levels will make sense of energy as an abstract concept and of social issues related to science and technology in a manner very similar to adults.

At the heart of the constructivist view is the idea that the conceptions held by each individual guide understanding. A further key aspect of this view is that knowledge about the world outside is viewed as human construction. A reality outside the individual is not denied; rather, it is claimed only that all we know about

reality is our tentative construction. Accordingly, learning is not viewed as transfer of knowledge but as the learner actively constructing, or even creating, his or her knowledge on the basis of the knowledge already held. There are social aspects of the construction process; although individuals have to construct their own meaning of new idea, the process of constructing is always embedded in a particular social setting of which the individual is part (Duit and Treagust, 2003). Therefore, another point of energy learning is that children's alternative concepts about energy stem from a context which is inappropriate for school science, but which is valid and valuable in their everyday world (Trumper, 1990a). This suggests that science teachers should think of the different existing ideas that were held by individuals.

Cognitive development is thought of as individuals constructing their own internal mental model of external reality, relatively independently of other people. However, in Vygotsky's view, children acquire the mechanisms of thinking and learning as a result of the social interactions between the children and the adults around them (Birch, 1997: 80 -81). Learning science is seen to involve more than the individual making sense of personal experiences. It is also being initiated into the way of seeing which has been established and found to be fruitful by the scientific community (Duit & Treagust, 2003). Vygotsky's theory emphasizes the importance of adults being aware of a child's ZPD and moulding their scaffolding behaviour to suit the child's existing knowledge and developmental level (Vygotsky, 1986). Teachers have to help shape student's views towards the inclusion of scientific notions in their personal framework of understanding. To do that, science learning has to be organized via contrived situations because it has to be a purposeful induction that goes beyond personal experience and personal knowledge (Hodson & Hodson, 1998). However, this could be difficult in a school situation, as in Thailand where teachers are frequently responsible for the learning of 50-plus pupils. Peer and cooperative group work may be one solution to this problem (Birch, 1997: 80 – 81). Research has found that children who had engaged in cooperative group work were less competitive, less concerned with status and more likely to display logical thinking than were children who had worked alone (Slavin, 1990).

The two views of constructivism, personal and social construct, are concerned with constructing mental representations of certain structures or features of the world outside that are stored in the human brain. From the personal constructivist perspective, learning is seen as construction of mental models. Knowledge then is something an individual constructs. The social constructivist perspective claims that knowledge can be distributed among the members of a certain community or shared by the community. Knowledge, then, is something that is between the individual and the social (Duit & Treagust, 2003).

A crucial part of science education involves learning about the nature of sciences. Learning science involves understanding the particular rationality that scientists employ in generating and validating knowledge claims. What that rationality is, and how it is influenced by social, economic, potential, moral and ethical factors, is a matter of some contention. Because of this debate, the view of teaching and learning science within the community of scientists has shifted its emphasis from personal construction by individual learners toward social construction and viewing learning as a process of enculturation. (Hodson & Hodson, 1998).

As the sociocultural view of learning, the cognitive apprenticeship proposed that working alongside an expert practitioner appears helpful to understand how student might learn. In this view, students can learn the process of generating power by going to observe and question what the engineer work to control the power plant. In other words, learning involves supporting between the socio-cultural and constructivist perspective to each other and should be recognized as a whole picture of learning and teaching (Packer & Goicoechea, 2000). According to Packer and Goicoechea (2000), they fantastically illustrate this relationship as: “The constructivist perspective offers an as if message: how we act as if we are mind, facing an independent world; the socio-cultural perspective offers an account of how we get to that point” (p.228). Thus, the socio-cultural suggests teaching and learning energy to focuses on issues such as how the thinking of students in different countries differ when approaching a problem; how learn energy in Thailand today differ from 50 years ago (Wertsch &Toma, 1995).

Applying the socio-cultural perspective, several cultural influences may be identified within the science and physics classroom. Several of these sub-cultures may interact in any given social institution; especially in the school system. Erickson (1987) reviewed the concept of cultures to help making sense for teaching and learning. His concept of culture consists of (1) culture viewed as knowledge bits that are stored in a large pool of information within the bounded social group; (2) culture as conceptual structures or central organising constructs that constitute what is taken as reality by members of a group; and (3) culture as political struggle where social structure and culture are treated as intertwined with strong patterns of differential sharing of cultural knowledge in the social unit. The concept of culture as shared ways of making sense suggests the existence of smaller social groups within the larger society.

With the important view of socio-cultural, we need to consider influenced different culture toward energy learning in Thailand. For carrying out science education research, the concept of culture is limited in smaller. Thus, the values, norms, and beliefs of larger society; the culture of scientific community; culture of learners; and school contexts will influence the Thai learning and teaching energy processes that will be discussed in next sections.

Socio-cultural Perspective in Teaching and Learning Energy

The socio-cultural view suggests that science teaching and learning should be concerned with the influence of society and culture on thinking in the classroom. Scientific knowledge as western culture is a particularly alien culture for Thailand. Therefore, the gap of different cultures should be taken into account for teaching and learning in Thailand. For the classroom, the culture is a small copy of society. In this section, the values, norms, and beliefs of the larger society; the culture of scientific community; the culture of learners; and the culture of school science in Thailand will be discussed. Then, the influences of these cultural perspectives on learning and teaching energy in Thailand are discussed.

1. Culture of Science or Scientific Community

Science is a social enterprise. A characteristic of scientific community involves working as research groups, each linking into a larger network sharing a common interest in an area of enquiry. Scientists can share scientific information through the process of conferences, journals, and peers. This mechanism helps the findings of individuals become transformed into public knowledge (Driver et al, 1996). Thus, the scientific community, alternative point, acts as on behalf of all citizens in the creation and criticism of the public knowledge. Scientists have to assess the reliability of the science produced. With the working of the scientific community, scientific knowledge is generated and validated (Ziman, 1978).

As the product of scientific community, the scientific ideas are tentative at each stage in their development. Therefore, it might be said that “what is ‘obvious’ today was ‘ridiculous’ yesterday and will be ‘false’ tomorrow” (Claxton, 1991: 80). The nature of scientific knowledge involves ontological commitments associated with the practice of science. Driver et al. (1994a) stated that “scientific knowledge is symbolic in nature and socially negotiated. The objects of science are not the phenomena of nature but it is construction that is advanced by the scientific community to interpret nature” (p.5). Thus, the things of science are no longer entities that populate a real world but the inventions of a scientific discourse which are “imposed on the phenomena” (p.5). Hence it is not nature which limits the scientific imagination but simply human capabilities and their cultural and conceptual tools which “reflect the cumulative wisdom of the culture” (Driver et al., 1994a: 5).

Scientific knowledge changes gradually all the time. With the continual changing of scientific knowledge, the question of how scientists can understand the scientific knowledge should be taken into account when teaching and learning science. At the centre of science is the attempt to generate a comprehensive account of phenomena in the natural world. This comprehensive account would give rise to accurate predictions, and therefore to the possibility of greater control within particular domains. This attempt is embedded within a context of personal

psychology and social influences. Therefore, an image of science is an image of reliable knowledge, obtained through standard methods of enquiry when faced with a dispute between scientists about some practical matter (Claxton, 1991; Driver et al, 1996). An understanding of scientific knowledge and the validity and interpretation of data are negotiated through social processes. Scientific disputes bring the relationship between science and society into sharp relief, and provide a useful context for enquiry. Issues about the role of evidence and of social factors shape the course of a dispute and influence the time and manner of its resolution (Driver et al, 1996).

The way of scientific community generated and understood scientific knowledge is the process involved in sharing a common interest in an area of enquiry and scientific information; negotiating and disputing scientific knowledge for shaping ideas and finding scientific solutions. This mechanism shows a view of scientific knowledge as tentative. The idea of how scientific community works, should be taken into account in teaching and learning science. If teaching science offers a way of generating scientific knowledge similar to that of the scientific community, it may create meaningful learning of science.

2. Culture of School Science in Non-western Societies

In the socio-cultural view, learning is always directly related to the situation and cultural activities (Kiraly, 2000: 43). Brown, Collins and Duguid (1989) describe the basic ideas of situation related to constructing knowledge as a term of “situated cognition”. Situated cognition means that cognitive processes differ according to the domain of thinking and the specifications of the task context (Coll et al. 2005). Term of situated cognition raises the question of the cultural influence on conceptual knowledge.

According to Brown, Collins and Duguid (1989), conceptual knowledge is a function of culture and the activities of the community in which the concepts have been developed. Therefore, conceptual knowledge cannot be abstracted from the

situations in which it is learned and used. It is partly a product of the activity, context and culture in which it is developed and used. Conceptual knowledge may be considered as a set of tools. Learning how to use these tools as practitioners use them requires learning, like an apprentice, to enter that community and its culture. At school, students learn science that is shown the tools by practitioners (e.g. scientists). The school culture observes these tools to be different from the practitioners' culture. Therefore, teachers need to be aware of these differences.

However, science teachers were often showing a false image of science (Claxton, 1991). Science teachers themselves have little knowledge of the culture of science. Traditional school science developed incorrect beliefs about the culture of science. These beliefs were reflected by that science develops in a linear like the table content in a book; advances in science are the result of the periodic efforts of men, acknowledged to be in the genius category; the scientists are motivated essentially by the ideal associated with the development of knowledge; science evolves independently of the socioeconomic and the cultural context of the time (Nadeau & Desautels, 1984).

To change the almost idolatrous attitude toward science of students, teaching science should include the history of science. The history of science considered socio-political and cultural contexts of some major scientific achievements and inculcate in students a critical approach to scientific activity (Nadeau and Desautels, 1984). Bridging the gap between scientists' science and the way it is represented in schools should be considered.

Besides the difference between culture of scientific community and school science, the science in non-western country is one of factors that obstacle learning. Western style science education is seen as a stepping-stone (Tan, 1988). With western science being projected as a western construct the concept of ethno science often referred to as indigenous science (Linden, 1991), is appearing in modern epistemology. The non-western country adapted the western science curricula to provide personnel in the area of science and technology required for national

development (Ingle and Turner, 1981). There are research and articles conducted in non-western country such as Samoa (Moli, 1991), Bostswana (Praphat, 1990), Nigeria (Okebukola and Jegede, 1990), Japan (Aikenhead and Otsuji, 2000) and Thailand (Pitiyanuwat and Sujiva, 2000) that indicated how beliefs, norms, and values of students from non-western cultures are in conflict with the beliefs.

The issue of language is crucial factor for learning in science as it relates to non-western language learners. For this issue, Vygotsky provided a useful theoretical basis for understanding the connections (Rollnick, 1998). Learning science for learner, perceive western language as foreign language, is translated from western language that the gap between languages should take into account for understanding science. Japanese, for example, translate science as 'kagakugijutsu' but translation back into English come out as 'techno-science' (Aikenhead and Otsuji, 2000). According to meaning of science as techno-science in Japanese, it represents "how Japanese people have traditionally dealt with western science by treating it as a materialistic benefit rather than a way of knowing nature" (Aikenhead and Otsuji, 2000: 287). It might be say that the culture of science is alien culture for Thai teaching and learning because there is difference of culture, cognition and educational background. In western societies, science educators understand the fundamental, culturally based beliefs about the world that students and teachers bring to classroom (Cobern, 1998).

3. Culture of Learners

Before modern Thai education, public education only took place in Buddhist temples, therefore, part of the value of education stemmed from Buddhist teaching (Pittiytanuwat & Sujiva, 2000; Fry, 2002; MOE, 2004). In period of the modern Thai education, public schools and universities were established. To attend those educational institutes, students need to take entrance examination. Unfortunately, there are different qualities among those schools. Therefore, most students want to attend in the most well-known schools. It can be said that the characteristics of most

Thai learners have evolved from Buddhism philosophy (Pittiytanuwat & Sujiva, 2000), and driven by the gap in educational opportunities (Kaewdaeng, 2003).

Thai learners value education as memorised knowledge for taking examinations, rather than as a basis for lifelong learning (Kaewdaeng, 2003). Students have to take an entrance examination to study in Grades 1, 7, 10 and in universities. The entrance examination is a real goal of education for students and their parents. In order to achieve high scores, to apply for the well-known schools and universities, students have to memorise knowledge for taking the examination. This need means that students must take supplementary study in a tutor school outside their normal school time. This tuition in tutor schools expands the gap of students' opportunity of education between students in city and country; between poor and rich students. This culture of learning raises the competition of studying, but memorising knowledge does not correspond with learning science.

The learners who emerge with a Buddhist view might appreciate the scientific method because the Four Noble Truths of Buddhism have the ideas which are quite similar to the scientific method. The Four Noble Truths of Buddhism consist of 'Tukh', 'Samutai', 'Niroth', and 'Mahk'. Pittiytanuwat and Sujiva (2000) clarified these terms as below:

(1) 'Tukh': perceiving the state of suffers as their real condition (Tukhata). This process of clarification and identification of suffers must be understood and its limitations defined. (2) 'Samutai': realizing what causes suffering and learning how to eliminate it. This process involves the investigation, analysis and diagnosis of the causes of suffering. (3) 'Niroth': realizing the state of the elimination of suffering and clarifying it. This process involves realizing what the destination of suffers is, and understanding the possibility of attaining that destination. (4) 'Mahk': refers to the conductions for attaining the elimination of suffering that must be practised. This process involves taking steps to eliminate suffering and then conducting them oneself (Pittiytanuwat and Sujiva, 2000: 84).

Therefore, the scientific ideas from a western perspective might be not totally alien for mainstream Thai teaching and learning science. However, the Thai identity is rooted in Buddhist view of the middle way and a simple style for living (Wisadavet, 1996). This identity is integrated and has become the characteristic of the Thai learner. This identity might be an obstacle to learn extreme scientific and technological knowledge. As the view of middle way, Thai have inspiration for creative thinking in science and technology at the moderation level rather than at the extreme level (Wisadavet, 1996). An obstacle of developing extreme scientific and technological knowledge can be insight by considering developmental working of Thai farmer. Thailand is an agricultural society. Most of Thai are farmer who grow rice (ONCC, 2004). Thai traditional farmer did not develop gradually science and technology for their product. With living style as middle way, it might be assumed that Thai farmer have no inspiration to apply technology because there is no serious agriculture problem. The weather usually does not change seriously and, therefore, farmer can grow naturally rice that mean it depend on weather.

Sometimes Buddhist beliefs did not encourage the learner to consider creating new innovations in science and technology because the Buddhist perspective does not encourage the production of material wealth. This opposes the dominant materialist world-view which regards science and technology as the solution of all problems. Western views of science and technology aim to develop a materialist and mechanistic world-view. The Buddhist position is self-development that involves cultivating a person's own mind. "The aim of Buddhism is not to shape life in the world, but to teach liberation, release from the world. The Buddhist attempt to attain inner peace (Nibbana) through self-development is understood as an absolutely personal performance of the single individual" (Premasiri, 1996). This perspective shows why Thai traditional educators or literates, educated in the Buddhist temple, had never been interested in studying science and technology. The history of studying science in Thailand is not deep rooted as in the western countries but origin of science can be traced back to the middle nineteenth century. The history of studying science began with King Mongkut (Rama IV), the Father of Science in Thailand. This king

was keenly interested in astronomy and accurately predicted the occurrence of a total eclipse over Wa Ko, a subdistrict in Prachuab Khiri Khan, on 18 August 1868.

4. Culture of Thai Community

There are number of cultural perspectives in Thai community that influence Thailand values education. The values education in Thailand is based on religion, mainly Buddhism; Thai identity and tradition (Wisadavet, 1996) and the economic development (Pittiyatanuwat & Sujiva, 2000). Some of these perspectives can be supportive of teaching and learning science but some of them can be obstructive.

The Thai living style is to live peacefully together. The Thai norm is to respect seniority; therefore the Thai attitude is one of humility. Children are taught that good children must obey parents, teachers and adults (Titthummo, 2004). The view of seniority can be shown in the proverb about obeying adults, ‘Phu yai arb nam ron ma kon’ or ‘dern tam phu yai ma mai kad’ (Adults see the world before children, so children should obey them). It might be said that this view holds the Thai worker to the work place. Thai workers follow what their head orders without disputing or negotiating the best way for their organization. In the classroom, learning science tend to lack discussion because students might believe that good students usually do not say anything that might oppose what the teacher is teaching.

Thai identity stems from the Buddhist view. The Buddhist principle of no-self (anatta) teaches Thai that should not be strongly attached to things. Everything is changing. This is the reason why Thai are quite flexible and pragmatic (Wisadavet, 1996) and Thai society can accept easily foreign culture. In modern times, Thailand received scientific and technological perspectives and things from the western countries. Thai regards science and technology as helping to develop the nation. This Buddhist principle of ‘anatta’ might support Thai students, to be able to more easily understand the nature of science.

With the globalization, Thailand has accelerated economic growth during the late 1990s (NESDB, 2002; Pitiyanuwat, & Anantrasirichai, 2002). The expansion of export-oriented industries has contributed to the high rate of economic growth. This expansion needs human resources. With a rising requirement for people in the industries, the educational institutions must produce people to serve those industries. The technician is the fastest solution to rapidly expand industries, but it is not the best solution in the long run. The economic factor affects the value education. The ways of learning science follow scientific knowledge prescription that it is enough for producing the technician.

5. Socio-cultural Influences on Teaching and Learning Energy in Thailand.

The teaching and learning energy is influenced by the socio-cultural perspective. There are several culture influences in teaching and learning science. Applying socio-cultural perspective in teaching and learning energy, this research focus on embedded on cultures into energy classroom including culture of school science, communities, scientific communities, and learners as seeing in the Figure 2.1. However, this view of cultures will be narrow into energy classroom. Each aspect is discussed below.

Culture learner is one of the factors that should be taken into account for energy teaching and learning. Thai learners value education as memorised knowledge for taking examinations, rather than as a basis for lifelong learning. This would be generated from taking an entrance examination to study in Grades 1, 7, 10 and in universities. The entrance examination is a real goal of education for students and their parents. This need means that students must take supplementary study in a tutor school outside their normal school time. . This could assume that students have to memorise knowledge for taking the examination.

Considering culture of Thai communities, the Thai norm is to respect seniority; therefore the Thai attitude is one of humility. In the classroom, learning science tend to lack discussion because students might believe that good students

usually do not say anything that might oppose what the teacher is teaching. This seems to be obstacle for science learning that require negotiating and the valid and interpreting of data through the social processes.

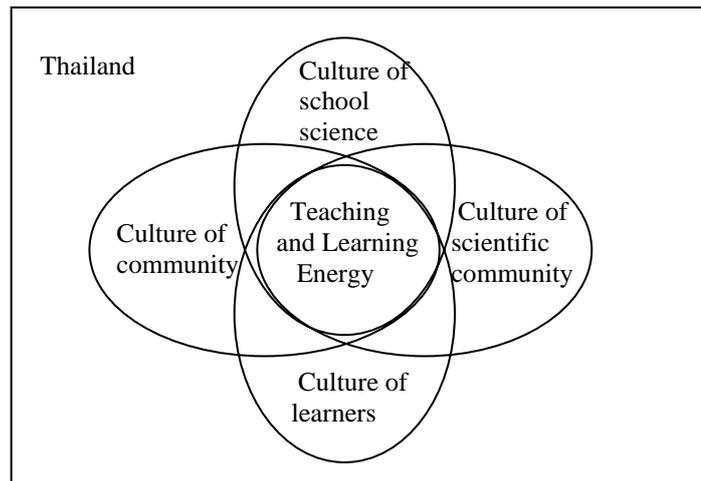


Figure 2.1 the Influenced Socio-Cultural Perspective toward Teaching and Learning Energy

To appreciate in teaching and learning science, teachers and students needs to perceive what the nature of scientific knowledge is, what kind of scientific communities, how scientists can understand and develop scientific knowledge. However, teaching and learning science aims not only to produce scientist but also provide citizen in the science and technology era. This purpose leads to the scientific and technological literacy for all. Teaching and learning science needs to shares two common aims. Because of, first, the aim of helping students come to an understanding of some parts of the corpus of substantive scientific knowledge; and understanding the nature of science and scientific knowledge underpins successful science learning. Second, scientists are citizens (Driver et al., 1996).

An understanding of scientific knowledge is negotiated and the validity and interpretation of data through the social processes. Scientific disputes bring the relationship between science and society into sharp relief, and provide a useful context for enquiring. Historical controversies offer contexts for exploring the development of more accessible scientific knowledge. Often this may involve the

learning of scientific ideas which are no longer accepted. However, the use of historical materials in school science is not without its attendant problems (Driver et al, 1996).

Teaching and learning energy account for the socio-cultural perspective that concern on the influence of cultures to interact in energy classroom. This suggests that situation of society influences for constructing energy knowledge (Billett, 1996). The situation of society and technology context is crucial one for learning energy because the relationship between science technology and society support and emerge to each other. The next section will discuss energy learning in technology and society context.

Energy Learning in Technology and Society Context

The theory of learning such as social constructivist and socio-cultural view suggest that students can construct their own knowledge while they interact in social or cultural activities. Energy learning relates to technology and society context. Learning, therefore, should account the influences of technology and society context. This section will discuss the nature of social and technological context, how they influence energy learning, and the influence of social and technological context inform what aspect support meaningful energy learning.

1. Social Context Influences on Energy Learning

The present society is society of science and technology. There are many perspectives that society is taken involve in science and technology. Rosenthal (1989) scoped relationship between science, technology and society as two perspectives including social issues and social aspects of science. Social aspects of science involves focusing science and technology with aspects of philosophical, sociological, historical, political, economic, and humanistic. Philosophical aspects refer to the nature of science, the impacts of scientific discoveries on society, and the social responsibility of scientists. Sociological aspects refer to the influence of

science and technology on society, the influence of society on scientific and technological progress, and the possibilities and limitations of using science and technology to solve social problems. Historical aspects refer to the effect of historical events on the rise of science and technology. Political aspects refer to the interactions among science, technology, the public, government and legal system; and decision-making about science and technology. Economic aspects refer to the contributions of science and technology to economic development; interactions between science, technology and industry; and economic factors affecting science and technology. Humanistic aspects refer to the aesthetic, creative and cultural aspects of science and technology; and influence of the humanities on science and technology (Rosenthal, 1989; Aikenhead and Ryan, 1992). Social issues required scientific and technological knowledge to solve the social problems. The social issues related energy is one of social issues that impinge on everyday life. Citizens are often required to make decisions about socio-scientific issues. The problems such as nuclear energy, energy use, or pollution are issues on which scientifically and technological literate students and citizens need to make decisions under framework of social aspects (Bingle and Gaskell, 1994; Ratcliffe, 1995; Jones, 1997).

The public decision making about social problems related energy required well understanding of energy concepts. The literature review found that students are confused with assumptions of energy in science class room and everyday notions. Solomon (1983a) described, in daily life conversation and through the mass media, students (English speakers) are confronted with implicit assumptions about energy which can be directly at odds with the scientific explanation. Outside school, these students are continually being socialized into a whole sort of non-scientific explanations. From this standpoint the persistence of such socialized knowledge becomes readily understandable (Solomon, 1983a). In Thai context, the daily life conversation seems to affects energy concepts. Yuenyong et al. (2005) found that student perceived the law of conservation energy as saving energy. This student perception might be generated from socialized knowledge because there are, now, amount of advertisement and campaign for saving energy in Thailand. The gap between the two different domains of knowledge as everyday notions and scientific

explanation should be closed. Crossing over from one domain of meaning to the other involves an abrupt discontinuity student thought. Lesson energy should offer the relationship between science, technology, and society in order to give students to generate continually and apply their scientific ideas in society (Bingle and Gaskell, 1994).

The influences of social issues related energy require students to use scientific explanations for communicating and negotiating to reach decision making. This view is a broad consensus of improving scientific and technological literacy (STL) (Solomon, 1992; Bingle and Gaskell, 1994). The central part of decision making is a critical examination of the relevant scientific knowledge involved (Bingle and Gaskell, 1994). Giving students to consider decision making about energy issues; it might enhance student meaningful learning energy because it serves the answer of why students need to study energy.

2. Technological Context Influences on Energy Learning

The nature of technology was interpreted through various views including applied science (de Vires, 1996), practical method (Gardner, 1994; Jones, 1997), artefacts, techniques, design, invention, innovation, volition, systems (Hansen & Froelich, 1994; Gardner, 1997), social process (Naughton, 1992), and cultural phenomena (Jones, in press).

The most popular of technological perception is technology as applied science and artefacts (Liligeto, 2001). For example, engineering concepts often need to be developed or utilised in the realisation of a technological solution. Technology was viewed as products, implementing of ideas, and artefacts. The produces were the end result of an application and practice (Swernofsky, 1989). The artefacts means instruments, machines and hardware which are invented the result of the design processes (Hansen & Froelich, 1994; Mather, 1995). The implementing of ideas involves the products of man vision, imagination and self sustaining process (Shield, 1996; Swenofsky, 1989).

The deeper view of technology, it should be interpreted beyond the image of artefacts and applied science (de Vries, 1996). Jones (1997) claimed that technological perception as artefacts and applied science is quite narrow view of technology. Technology should be perceived as not only applied science but also economic, social, personal, and environmental needs and constraints (Jones, 1997). The technology should be perceived also a system involving an organisation, procedures, symbols, new words, and a mind set (Conway, 1994). Technology as system theory, for example, Marx's case, he developed a historical teleology of social progress in which the working class would ultimately own and control machinery as the means of production (Hansen, 1997). The perception of technology beyond sense of artefacts and applied science, it could be interpreted through the social process. Technology, therefore, is a range of human activities, value, judgements, definition of content and selection processes (McCormick, 1993). In this sense, technology involves the application of scientific knowledge to practical tasks by organisations that involve people and machine (Naughton, 1992). The technological knowledge and practices are socially constructed and context dependent and where human mental processes are situated within their historical, cultural and institutional setting. In other words, the interpretation of technology through social process involved technological developments that have been shaped by people making decisions based on their own and others opinions and interests. This supports technology as a value-laden activity and citizens need to understand and control decision making (Jones, in press). With the social and context construction, technology, therefore, could be interpreted in view of cultural phenomena. According to Bunge (1973), technology is a major organ of contemporary culture and is seen as a basis to develop culture. For example, technology can be seen as the way that people represent culture such as science, mathematics, music, and so on (Jones, in press). Hansen (1997) described the meaning of technology through social relation that raised the three types of cultural meaning of technology including the motivational, topical, and practical or interpretative meaning. The topical meaning corresponds with curriculum content, conceived as a selected part of the students' reality. Motivational meaning refers to the interests people develop in technology and involves a social process of exercising choice in ways derived from cultural values and norms. The interpretive meaning of

technology refers to the practical means of designing, communicating and understanding technology (Hansen, 1997).

Conclusion, in view of non-vocational education, technology is not only artefacts, tool, or products; but also the ideas, design, systems, volition of application scientific knowledge that is socialized by values and norm before becoming products. Technology, therefore, involves selection process of application scientific knowledge under condition of economic, social, personal, and environmental needs and constraints.

With the deepen view of technology, it illustrates holistic view about how the technological context influence science (energy) learning. The influences of technological context raise the importance of providing citizen and suggest the relationship science and society, and scientific knowledge development. The technological aspects reflect how the relationships between science and society are (Jones, 2003). People need to be technological literacy. Technological aspects, therefore, is skills to support people decision making. The understanding of what, why, and how ideas, design, systems, volition of application scientific knowledge and other knowledge (e.g., philosophical, sociological, political, economic, humanistic aspects and so on) work becomes key aspects of surviving in society. For example, citizens have to make decision about energy issues (e.g. energy use, saving energy, and pollution) that they requires technological idea. The technological view of design support public decision making. The focus on design links technology to general cognitive abilities. This aspect public rhetoric about energy and technology becomes dominated by dichotomies like ‘chances and problem’, ‘advantages and disadvantages’, or uses and abuses’ (Hansen, 1997). As goal of provide citizen, this suggests that energy learning should account technological aspects for enhance students to perceive the relationship between science, technology, and society.

The technological aspects might support student understanding the nature of scientific knowledge because it supports student to see the tentative of scientific knowledge, and the rational of scientific development. Students might be motivated

to think about the rational and the social context of the material artefact, for example, thinking about what people interest in the development of steam engine is (Hansen, 1997). Scientific information needs to be reworked and translated into different forms for use in technological practice that relies on accessing multiple knowledge bases. Technological practice involves interesting to use scientific knowledge or to make energy ideal coming true under condition of social aspects. Technological practices, therefore, might suggest student to perceive scientific knowledge development (Jones, in press).

3. Energy Learning as Informed by Influences of Society and Technology Context

The influences of science and technology context suggest that decision-making should be taken into account for energy learning. The decision making requires people who have higher order thinking skills to apply value judgments and other knowledge (Kortland, 1992, 1996, 1999; Bingle & Gaskell, 1994; Ratcliffe, 1995, 1997). Therefore energy teaching and learning through STS approach requires students' decision making and higher order thinking skills. The thinking skills and decision making are clarified below.

Term of higher order thinking skills was clarified concerning with the classical scientific inquiry skills and cognitive activities. Most of the classical scientific inquiry skills, such as formulating hypotheses, planning experiments, or drawing conclusions are also classified as higher order thinking skills. Cognitive activities involves defining the higher order thinking skills beyond the stage of understanding and lower level application according to Bloom's taxonomy. Based on Bloom's taxonomy, memorization and recall of information are classified as lower order thinking whereas analyzing, synthesizing, and evaluating are classified as higher order. Additional examples of cognitive activities that are classified as higher order include constructing arguments, asking research questions, making comparisons, solving nonalgorithmic complex problems, dealing with controversies, and identifying hidden assumptions (Zohar and Dori, 2003).

Decision making is perceived as a process that has to do with issues, solutions, values, action taking (Ratcliffe, 1995; Kortland, 1996). As a process, decision making is the making of reasoned choices from among alternative courses of action that concerning a personal or public issues, which require judgements in terms of one's values. This process ideally should proceed have led to the formulation of a normative model for the decision making process (Kortland, 1996). Normative decision making models give a logical structure of step-by-step processes which should be undertaken if rational decision making is to take place (Raticliffe, 1995). In general, practical idea of normative decision making model is a step wise of procedure of identifying the nature of problem, developing criteria, generating and evaluating alternatives, and finally choosing and implementing the best solution (Raticliffe, 1995; Kortland, 1996).

To provide framework of examining and describing student decision making for carrying out research in science education, the framework of normative decision making model was employed quite similar by Kortland (1992, 1995, 1996) and Raticliffe (1995, 1997). According these research, the common themes of the normative decision making model could be concluded as containing six steps.

- (1) Options. List or identify the possible alternative way of action in considering the problem or issue.
- (2) Criteria. Develop or identify suitable criteria to use for comparing these alternative ways of action. The nature of these criteria is left open to discussion.
- (3) Validity and clarify of information of each criterion. Clarify the information known about possible alternatives, with particular reference to the criteria identified and to any scientific knowledge or evidence.
- (4) Evaluation or survey. Evaluate the advantages and disadvantages of each alternative against of the criteria identified. Or, weight conflicting results of the comparison on different criteria.
- (5) Choice. Choose an alternative based on the analysis undertaken.
- (6) Review. Evaluate the decision making process undertaken, identifying and possible improvement.

With the goal of science education, students are expected to understand the relationship between science, technology and society. The framework of normative decision making model suggests how to support students to consider the factor of relationship between science, technology and society. Lesson energy, gives chance students to learn energy related decision making in group discussion or individual about energy issues, might enhance student learning to achieve goal of science education about understanding the relationship between science, technology and society. Next section will discuss about teaching through the science, technology and society context.

Energy Teaching Through Science, Technology, and Society Approach

This section clarifies how apply energy teaching and learning through STS approach. The section begins with the significances of the STS, science teaching based on the STS, the designing the STS instruction and applying the STS approach for energy teaching. Each aspect is discussed as below.

1. Significances of Science, Technology and Society Perspective

Science and technology play an increasingly influential role in everyday life but there is a little increase in the public understanding of this development (Jenkins, 1990). Science educators and educational organizations perceived as a crisis in scientific and technological literacy (STL). Current science education needs to address this crisis. Science, Technology and Society (STS) strategies are appropriate for promoting STL because the aims of the STS teach students the skills which allow them to become active, responsible citizens by responding to issues which impact their lives (NSTA, 1993; Yager, 1996b; Holbrook, Craven, & Lutz, 1996; and Yutakom, 1999).

In preparing the student for the real world, science teacher should teach what students will encounter in the future and show them how science knowledge can solve the social problems. There are problems of energy, such as energy requirement and

pollution reducing, energy depletion that can be recognised as global problems (Yager, 1996b). In Thailand, there are also problems of energy. For instance, there are issues related to consuming energy in Thailand such as the controversy of Bo Nok coal power-plant projects in Prachuap Khiri Khan province between electrical energy requirements and environment conservation (The Nation: August 28, 2001; September 5, 2001); and the conflict between generating power and the community fishery industry in Ubonratchatani Province. If the aim of school is a preparation for living, STS perspectives focus in teaching and learning energy would be an advantage for Thai students.

2. Teaching and Learning Science Based on Science Technology and Society (STS) Approach

According to the goal of science education, science for all is an important goal. It will provide people with the knowledge to understand a society which is influenced by science and technology. The discussions among science educators raise the importance of how STS issues could be incorporated into teaching and learning science. Science educators have suggested many ways of doing this (Fensham, 1988; Yager, Mackinu, and Blunck, 1992; NSTA, 1993; Yutakom, 1999; and; Jones, in press.). For instance, STS emphasizes decision-making and action to solve problems (Eijkelfof & Lijnse, 1988; Hunt, 1988); teaching strategies employ social issues related science and technology and students' experiences to introduce lessons (Hunt, 1988; Yager & Tamir, 1993; Yager, 1996b; Yutakom, 1999).

Science educators and practitioners, who regard integrating the relationship between science technology and society into teaching science, apply this perspective in several ways. To clarify what the characteristics of teaching and learning science based on STS are; what the goals for teaching science through STS are, how the international science educators attain STS perspective in science teaching, how science teacher can design STS instruction, and how science teacher assess student in STS instruction, these ideas will be discussed.

2.1 Goal of Science Teaching through STS

Among different goal of STS, it might be balanced as three general goals of STS including: (1) ‘acquisition of knowledge’ involves concepts about science and technology for personal matters, public concerns, or cultural perspectives; (2) ‘development of learning skills’ involves process of scientific and technologically inquiry for information gathering, problem solving, and decision making; (3) ‘development of values and ideas’ involves dealing with the interactions among science, technology, and society for local issues, public policies, and global problems (Bybee,1985: 85; Ryan, 1992:57).

Among its various goals, the central part of STS involves integration of science technology and society that that has an effect on students’ experience. STS is about making sense out of life today and for the future. It is also expected to educate for the social responsibility in collective decision-making on issues related to science and technology. Such issues require a harmonious mix of ‘a scientific-technical elite’ with an informed citizenry. The pervasive goal of social responsibility in collective decision-making leads to numerous related goals: individual empowerment; intellectual capacities such as critical thinking, logical reasoning, creative problem solving, and decision making; socially responsible action by individuals; and an adroit work force for business and industry (Aikenhead, 1994a).

There were many science educators that discussed the results of STS science education. Aikenhead (1994b) concluded that STS instruction was shown to have impact on students in the following ways:

1. Students become more capable at applying science concepts to new situations.
2. Students are better able to apply information, to relate information to other situations, to act independently, and to make decisions.
3. Attitudes towards science classes, towards the perceived usefulness of those classes, and toward science careers were much more positive.

4. Students displayed much higher frequencies of creativity.
5. Science process skills achievement was two to three times better in STS classes (p.180)

2.2 Attaining STS Perspective in Science Teaching

According to the different goals of STS there are several ways of attaining STS objectives. Looking at the whole view of STS science education helps the researcher to decide what and how to adopt the STS perspective into energy unit. The well-known Canadian science educator, Aikenhead, shows the whole view for practice in science education. Aikenhead (1994a) concluded the spectrum of STS content ranges from the lowest priority to the highest priority compared with traditional science content where content prepares students for the next level of education and to learn correct answers. This spectrum contains the range of eight categories of STS content including: (1) motivation by STS context; (2) causal infusion of STS content; (3) purposeful infusion of STS content; (4) singular discipline through STS content; (5) science through STS content; (6) science along with STS content; (7) infusion of science into STS content; (8) STS content.

There are many STS courses and units that are used across the world. Some of the STS course and units will be clarified here in order to suggest how to construct the energy unit in STS perspective for Thai students. The STS course will be demonstrated using the examples of the Science and Technology in Society (SATIS); the Dutch Physics Curriculum Development Project (PLON); the Iowa STS program; and some applications of STS courses in Thailand. Each of them is clarified as below.

2.2.1 The Science and Technology in Society (SATIS)

The Science and Technology in Society (SATIS) was established in 1984 as stipulated in the UK curriculum reform. The SATIS projects arose from a

concern that school science failed to draw on the everyday experiences of students; and failed to prepare them for their working lives. Thus, the SATIS units were provided as a crucial application of STS that emphasised solving socially related science and technology problems (Hunt, 1988).

The SATIS units were written by members of the Central team of SATIS but contributions were received from all over the country. With the method of sharing ideas between Central team and teachers, finally, the materials were published as the 100 SATIS units that were clustered into themes such as material, energy, the environment, health, ethical issues (Hunt, 1988).

According to Hunt (1988), the SATIS units introduced learning strategies including discussions, role-plays, survey, and reflective reading. In discussions, students are guided by the teacher through a coherent debate about relevant issues after they have informed themselves with relevant knowledge. Role-play emphasises bringing out the various view points of the interest groups represented. Surveys are conducted by the learners to collect data about relevant issues for their own analysis. And, students read reflective material on relevant issues because the questions in SATIS units were designed to encourage students to read reflectively.

The evaluations of the SATIS projects were carried out based on responses to a postal questionnaire, classroom observation, and interviews with teachers during school visits. The findings of the evaluation showed that the discussions were more likely to be satisfying for students if there was a clear end-point. Students liked to use hands and mind creatively to produce, for example, a poster, a newspaper article, a map, or a plan (Hunt, 1988).

2.2.2 The Dutch Physics Curriculum Development Project, (PLON)

The PLON project started in 1972 by the Physics Department, University of Utrecht, Netherlands. The project aimed to promote the abilities of

students to use physics knowledge in daily life situations (Eijkelkof & Lijnse, 1988). The PLON (1984) project is the development of physics curricula which integrate of physics, technology, and society. The teaching material that contain physics (basic concepts and skills which is useful in everyday life regarding decision making situations on a personal and social level (Eijkelkof & Kortland, 1988; Eijkelkof, 1994).

The PLON project produced about 40 units of materials which were dealt with in personal, social or scientific contexts in order to be meaningful to students. The units consisted of Traffic, Music, Weather Changes, Ionizing Radiation, Matter, Energy and Quality, Electronics, and Electrical Machines. The materials involved the use of physics in daily life, for example, to interpret media messages, to follow new developments in science and technology, to make consumer choices or to participate in public decision-making (Eijkelkof & Lijnse, 1988). Each thematic teaching unit is constructed in five stages: (1) an orientation stage, students are shown the relationship between a specific physics domain and an everyday context; (2) a stage of basic knowledge and skills concerning the topics is taught, preferably in the form of various student activities which stimulate independent learning in small groups; (3) a stage where students work on different options in parallel groups; (4) reporting, students report back their findings to the rest of the class, aimed at broadening and deepening their knowledge; and (5) Optional sessions, students may further explore the area depending on their interests (Eijkelkof and Kortland, 1988).

The units were provided based on posing a question that was relevant to students in order to present in the orientation of the unit to engage students' attention. The question also acts as an organizer to determine the knowledge and skills that have to be taught in order to allow students to find answers to a question. And, the question turns up again to provide practice and reflect upon the use of physics context (Eijkelkof & Lijnse, 1988).

For illustration what kind of the PLON unit likes, the questions of the popular unit of ionizing radiation will be shown here. The main aim of this unit is for students to learn to use scientific knowledge in reasoning about radiation risks. Students were required to answer physics questions similar to those of a traditional physics class. The questions included; ‘What is the origin of ionizing radiation?’, ‘What are its properties?’, and ‘How can this radiation be detected?’ And, students were required to answer questions that were not common in physics education because they combined by many subtopics such as biological effects of radiation and radiation protection, medical application, radioactive waste, nuclear arms, and procedures for evaluating risks. The questions included ‘What are its effects on human beings?’, ‘What use can be made of this radiation?’, ‘How can one protect oneself against radiation?’, ‘How can the radiation risks be evaluated?’ (Eijkelkof, 1994).

Modifications to the PLON units were carried out by questionnaires for students and teachers, meeting with teachers, class observations and interviews with students and teachers. Finding of evaluation showed a number of cases the students were confused by learning requirements in the PLON units which differed in previous physics lessons (Eijkelkof & Lijnse, 1988). This informs that the STS is alien approach for students.

2.2.3 Science and Social Issues

The Iowa STS program was conducted by the University of Iowa, USA. This program was established in 1983 in an attempt to help teachers remedy the alienation of many students from science by using approaches that advocated the STS curricula (Yager & Tamir, 1993). The new approach advocated by the Iowa STS approach was based on constructivism. Yager and Tamir (1993) described that the program based on constructivism involved being: student centred; individualized and personalized and recognizing student diversity; using a variety of resources; based on cooperative work on problems and issues and considering students to be active

contributors to instruction; building on student experiences; assuming that students learn best from their own experience; based on planning the teaching and learning around problems and current issues.

The Iowa STS program emphasizes that STS instruction is oriented towards local issues (Aikenhead, 1994b). In this STS program, the Grade 4 to 9 students were taught by teachers who participated in the Iowa Chautaupa project during four years of research. About 300 teachers participated in three-day workshops on STS. The workshop helped teachers to develop their understanding in five domains; concept domain, process domain, application domain, creative domain, and attitude domain (Yager and Tamir, 1993).

The concept domain involved students' understanding about facts, information, concepts, laws, principles, existing explanations, and theories being used by scientists. This domain was assessed by multiple-choice concept tests (Yager & Tamir, 1993).

The process domain encompassed the skills associated with exploration and investigation. Students can know the processes of science so that they are able to use them in a wide variety of situations. This domain was tested by the process test (Yager and and Tamir, 1993).

Application domain focused on the transfer and use of information, skills, and attitudes across contexts. This domain were seeing instances of scientific concepts in everyday problems; applying concepts and skills to everyday problems; using scientific processes in solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments; making decisions related life-style based on knowledge of scientific concepts rather than emotions; integrating science with other subjects; taking specific actions designed to resolve problems or contribute to the improvement of local problem; becoming

involved in community-action projects. This domain was tested by multiple-choice items focusing on possible uses of knowledge and skills in everyday life. Sample item was: “What are you assuming when you put the metal lid of a glass container under warm water to loosen it? (A) Both glass jar and metal lid increase in size in the same proportion; (B) glass increases in size in a greater proportion than the metal lid; (C) the metal lid increases in size in a greater proportion than the glass; (D) glass and metal do not stick together as much in water.” The choice ‘C’ is correct answer because, basic concept, metal increase in size when most metal objects are heated (Yager and Tamir, 1993).

Creativity domain involved developed students’ abilities for visualizing, imaging and combining ideas and objects in new ways. This domain was assessed by using question that provides students’ imagination. Sample question was “What would happen in a world without gravity? Write down as many as ideas you can that would occur.” (Yager and Tamir, 1993).

Attitude domain involved developing attitudes toward science in general, science in school and science teachers; developing positive attitudes towards oneself; developing sensitivity to and respect for the feeling of the other people; making decision about personal values and social environment issues. This domain was assessed by an 18 Likert-type items five point scale (Yager and Tamir, 1993).

After participating teacher on workshop of STS Iowa, teachers designed a 1-month STS module on their own. Teachers had their own students and a control group of students that students were pre-test and post-tested (Yager and Tamir, 1993). Yager and Tamir (1993) concluded finding of this research the following:

- With experience and high quality teachers, using the new approach did not produce more concept learning compared with using the traditional approach.

- With respect to process skills, creativity skills, and the applications of concepts processed to new situations; the new approach was more effective in all students.
- When the new approach was used with low ability students, they developed more positive attitudes towards science.
- In using the new approach, older students showed marked improvement in their skills of applying concepts and processes to new situations. Younger students improved more in their process skills and creativity skills.
- The gender difference found was in case of attitude. Positive attitude change towards science was observed in females in both treatments.

2.2.4 Attaining STS in Thailand

In Thailand, there are research that incorporate STS issues into teaching and learning science such as Chotethaisong (1996), and Chinawong (2001). For the latter one, he studied science teaching based on view of Science, Technology and Society by using the natural classroom. For Chotethaisong's (1996) research, she adapted Yager's idea of STS for teaching pollution. Her study aimed 1) to compare learning achievement in chemistry on the topic of pollution as caused by production and use of petrochemical products, and 2) to compare attitude towards pollution of two groups of Grade 11 students. These students were taught separately by using the Science-Technology and Society (STS) approach and conventional approach. Her research applied STS approach as:

- Raising the STS issues in classroom;
- Taking the various teaching strategies in order to enhance student's thinking and logical skills;
- Stimulating students to investigate information for solving these problems;
- Providing field trip, science camp, science projects that help students gather information of science and technology.

According to above research, it showed Thai science educators recognized that the STS perspective could help to link scientific idea and students' idea that stem from everyday life. However, there were a few STS research but there is no research that involved the Thai lay ideas of saving energy and generating power.

2.3 Designing STS Instruction

In STS perspective, science content embedded in a social-technological context. The NSTA (1993) concluded the obvious the characteristics of STS instruction as following ideas. Students can identify problems with local interest and impact. The use of local resources (human and material) locates information that can be used in problem resolution. Learning was extended going beyond the class period, the classroom, the school; and focused upon the impact of science and technology on individual students. A view of science content, therefore, is more than concepts which exist for students to master on tests. Teaching and learning emphasise process skills which students can use in their own problem resolution; opportunities for students to experience citizenship roles as they attempt to resolve issues they have identified (NSTA, 1993; Yager, 1996b).

Aikenhead (1994a) showed fantastic figure 2.2 to represent what characteristic of STS instruction is. According to Aikenhead (1994a: 57), the STS instruction begins in the realm of society, represented by the box in figure 2.2, by posing key question or problem; for example, 'Should the steam-electric power plant be constructed in our community?'. In order to understand a societal question or problem, there is usually some technology to examine. Technology is primarily concerned with developing knowledge and designing processes, in response to human needs and societal problems. Hence, social issues are related to technology.

A societal question (posed at beginning of the arrow in figure 2.2) creates the need to know certain technological knowledge (the donut area in figure 2.2). Both societal question and technological knowledge create the need to know some science

content (the content in figure 2.2). The science content will help students to understand the technology and the societal issues.

The sequence of instruction suggested by the arrow in figure 2.2 begin in the domain of society, moves through the domains of technology and traditional science, and then out again to technology. Students will make more sense out of the technology by using the science they have just learned. Thus, students will grasp a deeper meaning of the science and technology.

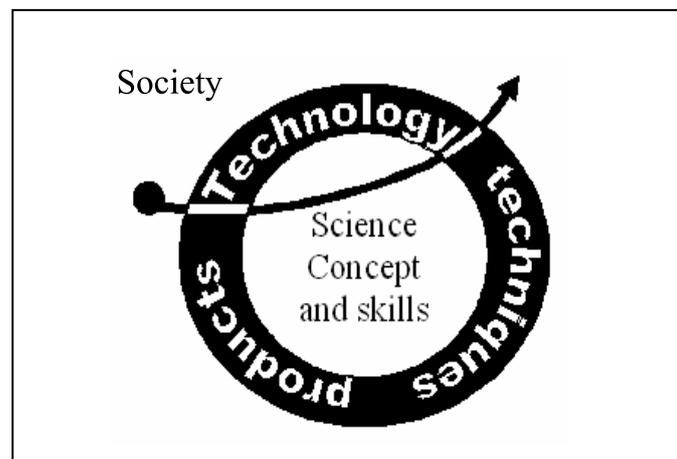


Figure 2.2 A Sequence for STS Science Teaching

Source: Aikenhead (1994a: 57)

Finally, the arrow in figure 2.2 ends in the domain of society. Here students often address the original key question or social problem and make decision. Students make decision informed by (1) an in-depth understanding of the underlying science; (2) a group of the relevant technology; and (3) an awareness of the guiding values. For instance, a class might decide what policy should be by the local electricity board concerning waste heat from the steam-electric power plant.

With the subject is abstract, energy concept should course among the concrete experiences of students in STS perspective. The figure 2.2 suggests a sequence that is useful for energy unit in STS perspective. Aikenhead (1994a) suggested that the lessons or units could be achieved by starting a class in the

technology domain (the donut in figure 2.2) with an interesting technology. Alternatively, teachers can begin with an interesting bit of science content, and move along the arrow from there.

From students' point of view in STS, the science content seems to arise from real life situation. This indicates that STS is student-oriented rather than scientist-oriented. Thus, the goals for STS science teaching will vary in each country and community. A curriculum's STS content will alter accordingly (Aikenhead, 1994a).

3. Applying Science Technology and Society (STS) Approach in Energy Instruction

This research concerns the STS perspective that Aikenhead (1994a) suggested shown in Figure 2.2. The developing the STS energy unit aims to allow students' energy learning through solving the issues about energy. The unit should give chance students identifying problems with local interest and impact about energy related technological and societal issues. Then, the unit allows them to experience citizenship roles as they attempt to resolve issues they have identified. The framework of teaching the STS energy unit, therefore, consists of five stages including an identification of social issues, identification of potential solutions, need for knowledge, decision-making, and socialization stage.

(1) Identification of social issues stage. This stage is designed to focus student attention and attitudes on learning about energy. The STS instruction has to begin in the realm of society. Instruction will be begun by posing issues related to energy use in society. These questions or problems of social issues need to be solved by citizens (Hunt, 1988; Jones & Kirk, 1990; Aikenhead, 1994a; Eijkelkof, 1994; Yager, 1996b). For energy concept, the issued of saving energy and the social problem related generating power should be brought into classroom by various strategies such as informing situation related these issues from posing in newspaper (Chotethaisong, 1996; Tsai, 2000); posing the social questions related these issues for allowing

students to participate in public decision-making (Eijkelkof and Lijnse, 1988; Kortland, 1995); seeing social problem by taking field trip (Hunt, 1988).

(2) Identification of potential solutions stage. Students plan to solve the social problem related to energy use. This stage supports students to concern with the technological aspects for find the possible solutions. Technological aspects are skills to support student decision making. Students need to think of what, why, and how ideas, design, systems, volition of application scientific knowledge work for that social problems (de Vires, 1996; Hansen, 1997; Jones, 1997). Teaching strategies may be used discussion among students' group, role-play (Hunt, 1988), brain storming, searching information via internet, and discussion with expert (e.g. engineers or scientists).

(3) Need for knowledge stage. This stage involves developing scientific knowledge. Social questions and technological knowledge create the need to know some science content. Energy concept was formulated in many strategies to help students to understand the technology and social issues. The strategies, for examples, include reflection reading document provided by teacher (Hunt, 1988; Kortland, 1996), and lecture. To give feedback students' understanding about energy concept, the short quiz (Dempster, 1992) will be taken after class of this stage.

(4) Decision-making stage. This stage involves student in making a decision on how to use energy knowledge and technology as solution of the social problem (Eijkelkof and Lijnse, 1988). This aspect public rhetoric about energy related technological and societal issues becomes dominated by dichotomies like 'chances and problem', 'advantages and disadvantages', or uses and abuses' (de Vires, 1996; Hansen, 1997; Jones, 1997). Student will be given chance to learn to choose between alternatives and in a thoughtful way systematically comparing as many relevant pro's and con's as possible (Kortland, 1996). Teaching strategies may be used discussion among students' group, role-play (Hunt, 1988), and brain storming.

(5) Socialization stage. Students need to act as people who are a part of society by reporting their proposal for solving problem. Student might exhibit their solution in public by produce a poster, a newspaper article or a plan (Hunt, 1988; Kortland, 1996), present science project (Chotethaisong, 1996).

Summary of Chapter 2

Chapter 2 clarified the information of the research problem and theories underpin that would give suggestions for carrying out the research, and then concluded the possible framework of energy teaching and learning through STS approach in Thailand. Each aspect is highlighted below.

The research problem was addressed based on the attempts for obtaining education reform. The indicators of education reform include both inside and outside school system. One of them involved science teaching and learning that emphasized on only knowledge rather than a chance for practice in analytical thinking, self-expression and acquiring knowledge by themselves. Considering to energy, there were many the issues about energy in Thailand. These issues require decision making that need people who have skills of thinking, problem-solving, and decision-making; and values that involve dealing with the interactions among science, technology, and society for local issues about energy. To solve these problems, education reform raised the crucial aspects of teaching and learning including a learner-centred approach and life-long learning. This suggests that students should have chance to be in touch and interact with all around them such as other people, nature and technology; and to apply learning methods to their real life.

To solve the research problem, the literature review of theories could give some possible resolutions. Learning theories raised the crucial aspects of socio-cultural view of learning. The socio-cultural perspective is concerned with the influence of cultures to interact in energy classroom (Billett, 1996). With the important view of socio-cultural, science educators are reminded the situated cognition. Situated cognition means that cognitive processes differ according to the

domain of thinking and the specifications of the task context (Coll et al. 2005). This suggests that energy teaching and learning would be influenced by the different contexts and cultures. Thus, the values, norms, and beliefs of larger society; the culture of scientific community; culture of learners; and school contexts should be taken into account for energy teaching and learning in Thailand.

This research, therefore, considers embedded on cultures into energy classroom including culture of school science, communities, scientific communities, and learners. Thai learners value education as memorised knowledge for taking examinations, rather than a basis for lifelong learning. This would be generated from taking an entrance examination to study in Grades 1, 7, 10 and in universities. The entrance examination is a real goal of education for students and their parents. This need means that students must take supplementary study in a tutor school outside their normal school time (Kaewdaeng, 2003). This could assume that students have to memorise knowledge for taking the examination. Considering culture of Thai communities, the Thai norm is to respect seniority; therefore the Thai attitude is one of humility (Titthummo, 2004). In the classroom, learning science tend to lack discussion because students might believe that good students usually do not say anything that might oppose what the teacher is teaching. This seems to be a obstacle for science learning that require negotiating and the validity and interpretation of data through social processes. To appreciate teaching and learning science, teachers and students need to perceive what the nature of scientific knowledge is, what kind of scientific communities, how scientists can understand and develop scientific knowledge. An understanding of scientific knowledge is negotiated and the validity and interpretation of data through social processes. Scientific disputes bring the relationship between science and society into sharp relief, and provide a useful context for enquiring (Driver et al, 1996). Learning, therefore, should account the influences of technology and society context.

Entering the relationship between science, technology and society in the energy class would be a possible solution because it supports energy learning by negotiating and disputing scientific knowledge through a socialisation process

(Aikenhead, 1994b). The issues about energy such as energy use, energy saving and pollution would elaborate students to realize the relationship between science, technology and society. The issues require students or citizens to make decisions under a framework of technological and social aspects. The social aspects involves focusing on science and technology with aspects of philosophical, sociological, historical, political, economic, and humanistic. Central to decision-making, technology is a crucial skill for citizens who need to consider multidimensional aspects in their decisions such as any social constraints (Bingle and Gaskell, 1994; Ratcliffe, 1995; Jones, 1997). Broadly speaking; technology is the ideas, designs, systems, volition of scientific applications and other knowledge that is socialised by values and norm before becoming products (de Vries, 1996; Hansen, 1997). The STS Energy teaching and learning, therefore, would allow students to learn energy through decision making for energy issues. According to the different goals of STS there are several ways of attaining STS objectives. This research emphasizes on developing the STS energy unit to allow students' energy learning through solving the issues about energy. The unit should give students chances of identifying problems with local interests and impacts about energy related technological and societal issues. Then allow them to experience citizenship roles as they attempt to resolve issues they have identified. The framework of teaching the STS energy unit, therefore, consists of five stages including an identification of social issues, identification of potential solutions, need for knowledge, decision-making, and socialization stage.

To provide people in the future, all students should have a chance to learn energy that related to technology, and society for local issues about energy. This research aims to enhance energy teaching and learning through STS approach in Thailand. Next chapter will clarify the research methodology regarding the interpretive paradigm.

CHAPTER III

METHODOLOGY

This chapter clarified the research methodology. The chapter begins with clarifying overview the methodological paradigms for research, the research methodology, the research design, and participants of this research. Then, the chapter will detail three phase of this research including the exploration, the intervention, and the evaluation phase. Each section is clarified next.

Methodological Paradigms for Research

This research seeks to interpret students' idea about energy transformation, conservation and degradation; and these concepts relate to society and technology; teachers' understanding about the concept of energy transformation, conservation and degradation; perception of these concepts related to teaching and learning; and how to enhance teaching and learning energy related to issues of science, technology, and society. This exploration tries to understand how to teaching and learning energy depend on the context that it is the centre of interpretive paradigm (Cohen et al., 2000). To provide the readers information, the methodological paradigms for research should be discussed. This section provided information of two views of research paradigms, the central issue of the interpretive paradigm, and then the value judgment of the interpretive research as the trustworthiness. Each aspect is discussed below.

1. Two views of research paradigms

The nature of educational research has changed, absorbing two competing paradigms of the social science, traditional and interpretive (Cohen, Manion, and Morrison, 2000). Firstly, the traditional paradigm holds that the social sciences are the same as the natural science. Therefore, the social sciences are concerned with discovering natural and social laws predicting individual and social behaviour.

Secondly, the interpretive paradigm emphasises not only the same concerns of traditional social science; but also the description of how people differ from each other, and human behaviour in different contexts (Lather, 1992; Cohen, Manion, & Morrison, 2000). Examining the differences of context and individual in detail, will develop a researcher's understanding of the issues

These two views of social science represent different ways of looking at social reality and are constructed on correspondingly different ways of interpretation. To clarify the research method in this research; the differences of these two views will be discussed here. Cohen, Manion, and Morrison (2000) analyzed these two views based on four assumptions including ontology, epistemology, and human nature, and methodology.

Firstly, ontological assumptions concern the essence of the social phenomena being investigated. The traditional paradigms hold that "there is no independently accessible thing constituting the meaning of a word." The interpretive paradigm contends that objects have an independent existence and are not dependent on the knower for existence.

The second, epistemological assumptions concern the bases of knowledge, how it can be acquired, and how communicated to other human beings. The traditional paradigm is in regard to the ways of the natural scientist or positivist view. In the positivist view, knowledge is hard and objective. The interpretivist views are anti-positivist.

Thirdly, human nature is concerned with human beings and their environment. The traditional or objectivist view regards human beings and their experience in a mechanistic or deterministic fashion and is concerned by their external circumstances. The interpretivist tends to be more subjective. The subjectivist is concerned with human beings in a more creative role with a perspective where 'free will' occurs. According the subjectivist, the human is the creator of their environment, the controller as opposed to controll, and the master rather than the marionette.

Finally, methodologically, according to ontologies, epistemologies, and models of human nature will demand different research methods. For researchers adopting a positivist (or objectivist) approach, they will treat method like the world of natural phenomena such as experiments, surveys. For anti-positivist (or subjectivist) approach, views the social world as being of a much softer; the method will be selected, for examples, participant observation, and personal constructs (Cohen et al., 2000)

2. Interpretive paradigm

A central issue of the interpretive paradigm is a concern with understanding the way in which the individual creates, modifies and interprets the world in which he or she finds himself or herself. This type of research provides an insight into an individual's perspective (Cohen et al., 2000). According to Denzin and Lincoln (1994), interpretation of the data is based on field work. Banister et al. (1994) said that the process of interpretation provides a bridge between the world and us, between our projects and our presentation of them. But, they also suggested that interpretation should always be viewed as a process. They further suggested that it is a process which continues as our relation to the world keeps changing. Tobin (2000: 87) further described interpretive research as an umbrella name for studies aimed at understanding communities, their actions, interactions and perspectives. Interpretive research seeks to answer broad questions and can address sociocultural factors not accessing easily using other methodologies.

The educational research is not scientific sense (i.e. empiricist or positivist). To contrary, interpretive inquirers are interpreters of the interpretations people give to their own actions and to actions of others, in other words, of interpretations people who already interpreted world (Smith, 1992). Therefore, the interpretivist stresses the importance of subjective experience that concern for the individual and focus on the action. Then, the search for understanding focuses upon the different issues and approaches them in different ways (Cohen et al., 2000). The concept of action for interpretivist is concerned with two key concepts including human and social action.

Human action is those expressions people make based on reasons, intentions, and motivations. The concept of social action is counted for because the meanings ascribed to human actions, both by the actors and the interpreters, are determined by a social content or within a network of social meanings (Smith, 1992).

The interpretive inquirer employed the various forms of method for interpretation but those methods have to run based on value of trustworthiness. The procedures employed by interpretive inquirer are the same as the procedures employed by qualitative researchers, that is, data gathering depends on interviews, observation, or the analysis. Interpretive inquirers also find value in such techniques as thick description, audit trails, member checks, and triangulation (Smith, 1992; Cohen et al., 2000). The trustworthiness details next.

3. Issue of trustworthiness for the interpretive research

With the positive paradigm four criteria have been used in value judgement including internal validity, external validity, reliability, and objectivity (Lincoln & Guba, 1985; Merriam, 1988; Altheide & Johnson, 1994; Cohen et al., 2000). Internal validity refers to the “extent to which variations in an outcomes (dependents) variable can be ascribed to controlled variation in an independent variable” (Lincoln & Guba, 1988: 290). External validity refers extent to which the findings of one study can be applied to other situations, or can be generalized (Merriam, 1988; Cohen et al., 2000). Reliability refers to the consistency and replicability of study, the extent to which the findings could be replicated across time, across method, and across samples (Cohen et al., 2000). Reliability is also a precondition for validity. Objectivity refers to the extent that the findings are influenced by the researcher, striving in the positivist manner for minimising any such influence (Lincoln & Guba, 1985). Application of these four positive criteria to interpretive research creates the difficulties. Alternatives conceptions to establish the trustworthiness have been suggested to account for these difficulties including credibility, transferability, dependability, and confirmability. These four issues are discussed below.

3.1 The Issue of Credibility

Credibility is recognized for the qualitative internal validity (Lincoln & Guba, 1985). Qualitative internal validity refers to represent people construction of reality adequately for the research to be deemed credible (Merriam, 1988). Credibility can be created by carrying out for the inquiry in a way that the probability that findings will be found credible is enhanced; and by demonstrating the credibility of the findings by having them approved by the constructors of the multiple realities being studied (Lincoln & Guba, 1985: 296). Lincoln and Guba (1985) suggested several techniques that can be used to increase credibility in a qualitative and naturalistic study including triangulation, prolonged engagement, persistent observation, peer debriefing, negative case analysis, member checks, and progressive subjectivity.

Triangulation is a technique that involves the integrative use of several elements in the collection of data. There are several types of triangulation including data source, methods, investigations, theories, time, and space (Lincoln & Guba, 1985; Merriam, 1988; Cohen et al., 2000). Data source triangulation involves the use of multiple participants providing one sort of data in one sense (Lincoln & Guba, 1985). Multiple sources could provide greater validity to data if reasons for the different sources can be found. Methods triangulation involves the use of different methods to gather data on the same object of study or using the same methods on the different occasion (Cohen et al., 2000). This triangulation may apply as mixing qualitative with quantitative data. Investigator triangulation is the use of more than one researcher. With the different researchers may elicit different data and may reduce investigator bias (Patton, 1990; Cohen et al., 2000). Theories triangulation involves the carrying out data as being viewed from the perspective of more than one theory providing the opportunity for wider explanation. Time triangulation involves collection of the data over times by making use of cross-sectional and longitudinal approaches. Cross-sectional study is collecting data that concern with time-related processes from different groups. Longitudinal study is collecting data from the same

group at different points in the time sequence. Space triangulation involves conducting research across cultural boundaries (Cohen et al., 2000).

Prolonged engagement in the field involves the researchers to become more familiar with the setting, and to build rapport and trust with the participants which identify spurious, unrepresentative information (Lincoln & Guba, 1985).

Persistent observation allows identification of the important elements in the study for detailed focus to be applied (Lincoln & Guba, 1985).

Peer debriefing involves the researcher subjecting themselves to an unbiased peer in a manner that might uncover concepts and assumptions that may have been implicit within the inquirer's mind (Lincoln & Guba, 1985).

Negative case analysis is the continuous revision of a formulated hypothesis in the light of the data until such time as all cases are accounted for (Lincoln & Guba, 1985).

Member checking involves subjecting the data, analysis and conclusion to the participants for their comment. It can be both formal and informal, and should occur regularly during a study. The checks provide participants and other stakeholders the opportunity to assess adequacy, intentionality, and to summarise; and gives the researcher the chance to get a critique of work (Lincoln & Guba, 1985).

Progressive subjectivity refers to extent which the researcher imposes own view on the reality being investigated, needs to be acknowledged (Lincoln & Guba, 1985).

3.2 The Issue of Transferability

Transferability is recognized for the qualitative external validity (Lincoln & Guba, 1985). The qualitative external validity rise issue of transferability. The

research focuses on human behaviour that there is its nature heterogeneous. The researcher must provide “the thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility”. In this sense, the researcher provides a highly detailed description of context such as extensive segments of verbatim transcript in case of interview (Lincoln & Guba, 1985: 316).

3.3 The Issue of Dependability

Dependability is recognized for the qualitative reliability (Merriam, 1988). Reliability in the interpretivist sense indicates consistency and replicability of the data. But, the interpretive research seeks to describe and interpret human behaviour based on their natural setting rather than form laws about it (Cohen et al., 2000; Merriam, 1988). Thus, the investigators of interpretivist preferred the notion of dependability that given a clear description of how data was obtained and open acknowledgement of context, the findings are acceptable within that context. This does not mean that the same results would be gathered in the same setting a second time (Lincoln & Guba, 1985). Merriam (1988: 172) suggested three techniques to enhance dependability. Firstly, the researcher should fully describe the assumptions and theory behind the study, their own position with respect to the group being studied, the basis for selecting participants and a description of them, and the social context from which the data were collected. Secondly, use of triangulation, particularly multiple methods of data collection and analysis. Finally, establish an audit trail that describes how data were collected, how categories were derived, and how decisions were made throughout the study.

3.4 The Issue of Confirmability

Confirmability is recognized for the qualitative objectivity (Merriam, 1988). Confirmability is more appropriate way of describing the objectivity of interpretive research (Lincoln & Guba, 1985). Confirmability concerns to ensure that the results of an inquiry have not been subject to influence by investigator. Thus,

confirmability can be enhanced by establishing a clear audit trail in which the reader can judge for themselves the potential influence of the researcher (Jones, 2002).

Research Methodology

This research is conducted regarding the interpretive paradigm. The interpretive research seeks to describe and interpret human behaviour based on their natural setting rather than form laws about it (Marriam, 1998; Cohen et al., 2000). Concerning the issue of dependability, therefore, given a clear description of how data was obtained and open acknowledge of context should be taken into account. This research enters the relationship between science, technology and society in the energy teaching and learning. The socio-cultural view was raised to interpret students' learning energy through the STS approach. As the socio-cultural view, the different culture of learner and context should be taken into account for teaching and learning energy. Therefore, this research is designed to carry out in the different school contexts in Khon Kaen province including school in the city, the small town, and the rural area. In the interpretive research, interpretation should always be viewed as a process. As the process of interpretation, this research aims to interpret students' ideas about energy concepts, energy related technological and societal issues and what teachers' existing ideas of energy concepts and perception of energy teaching and learning; and how to enhance teaching and learning energy related to issues of science, technology, and society. The interpretation of data is based on fields work. Therefore, according to the process of interpretation, this research was designed in three phases as following clarification.

1. Research Design

The research was designed in three phases under paradigm of interpretive research. These three phases include exploration, intervention, and evaluation phase. Each phase is clarified more below.

The first phase, exploration phase involved exploration students' and teachers' ideas in the different four schools including school A, B, C, and D. Exploring students' ideas involves ideas about energy concepts and energy related technological and societal issues. The school B, C, and D teacher ideas were explored to discover their understanding of pedagogical knowledge; and energy concepts. A range of student and teacher ideas will be interpreted to give the possible implications for teaching and learning based on the STS approach in next research phase. Student existing ideas were used to develop the STS energy unit. Teacher existing ideas will be developed assumptions to provide the program of enhancing the STS energy teaching.

The second phase, intervention phase is initially trialed the STS energy unit by the researcher in the school A. The researcher has been physics teacher for four year in the school A. This may be appropriate to initially learn what and how the unit worked before the further trialling in other schools by other teachers. The research outcomes of the initial trialling will give implications for the further trialling of the STS energy unit in the evaluation phase.

The third phase, evaluation phase involves enhancing the STS energy teaching and learning that could be viewed as the further trailing of the STS energy unit. The further trialling was carried out in three schools of Khon Kaen province, Thailand, including the city of Khon Kaen school (school B), the small town school (school C), and the rural school (school D). The program of enhancing STS energy teaching and learning was developed based on participating teachers' existing ideas.

The overview of the research design could be viewed as showed in the Figure 3.1. The time lines for the activities conducted during the three phases are showed in the Table 3.1.

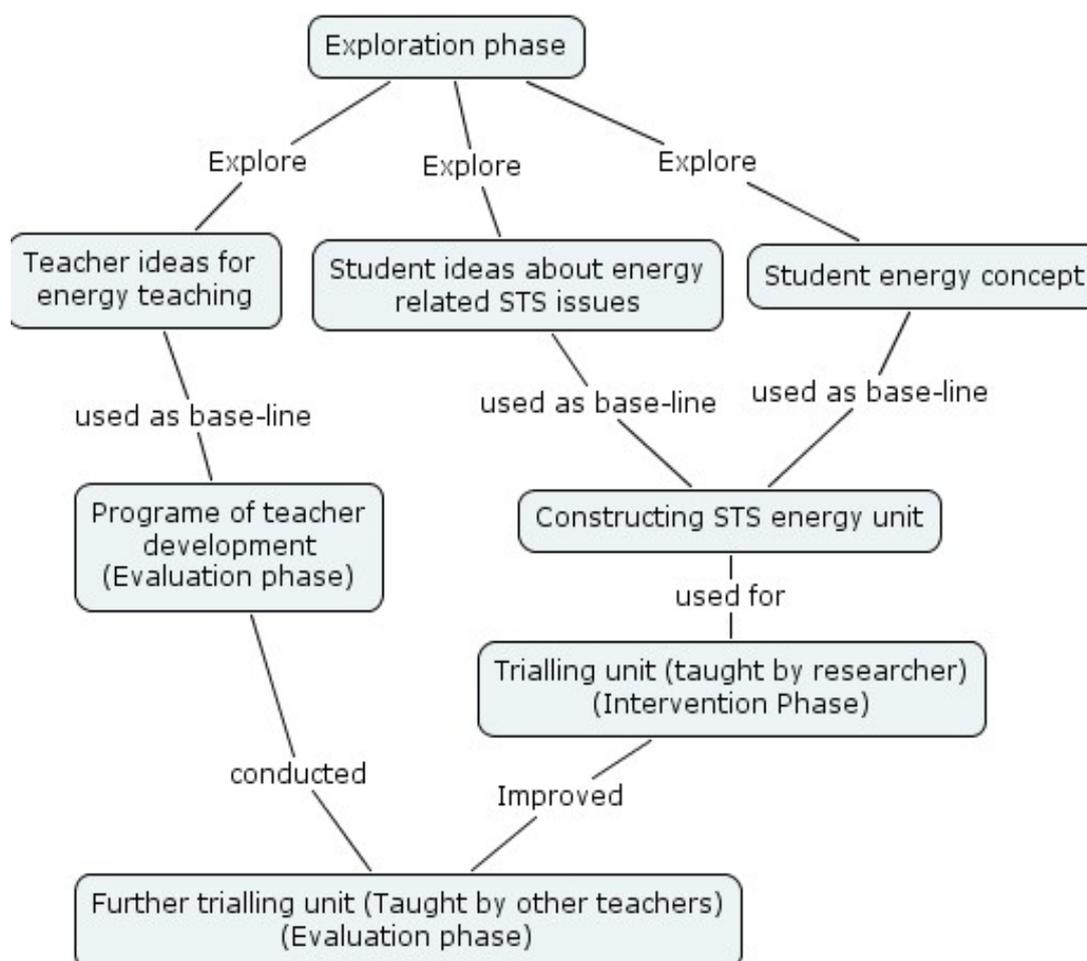


Figure 3.1 Research Design

Table 3.1 Research Time Line

Phase	Research Conducted	Date
1	Exploring student ideas Exploring teacher ideas	February to June 2004 May to June 2004
2	The STS Energy Unit: initial trial by researcher	August to September 2004
3	Providing teachers for enhancing the STS energy teaching The STS Energy Unit: further trial by three teachers	October 2004 November 2004 to February 2005

2. Participants

The research was carried with the 172 Grade 9 students in the different four schools of Khon Kaen province, Thailand including school A, B, C, and D. Each school context is clarified as following.

The school A is located in a university, Khon Kaen province. The total school A Grade 7 – 12 students approximately include 1,000 students. The school A has been very good supported by parent association and community; and it is usually treated as a laboratory for teaching and learning by a faculty of education. Grade 9 participants include 47 students, 27 girls and 20 boys, who live in a university and the city of Khon Kaen. The majority of their parents work in a university.

The school B is located in the city, Khon Kaen province. The total school B Grade 7 – 12 approximately include 3,000 students. Kunya is the participating teacher of the school B. She graduated the Bachelor of Education in home economic. Her science teaching experiences is 16 years. Kunya' school loading are not only science teaching but also the secretary of the school business affair. Her participating Grade 9 science class includes 49 students, 37 girls and 12 boys, live in the city of Khon Kaen and other small towns nearby the city of Khon Kaen. Their parents work for business sectors and government offices. The interesting source of energy learning in the school B is the Green Classroom that provided and financially supported by the Electricity Generating Authority of Thailand (EGAT).

The school C is located in a small town of the Khon Kaen province where far approximately 40 kilometres from the city of Khon Kaen. The total school C Grade 7 – 12 approximately include 2,500 students. Ann is the participating teacher of the school C. She graduated the Bachelor of Education in science for lower secondary school. Her science teaching experiences is 14 years. Ann' school loading are not only science teaching but also working for the school academic affair. Her participating Grade 9 science class includes 47 students, 25 girls and 22 boys, live in this small town and other villages nearby this small town. Their parents work as

private business, government officers, and farmers. The interesting source of energy learning in the school C is the Green Classroom that provided and financially supported by the Electricity Generating Authority of Thailand (EGAT).

The school D is located in a rural area of Khon Kaen province where far approximately 60 kilometres from the city of Khon Kaen. The total school D Grade 7 – 12 approximately include 600 students. Pim is the participating teacher of the school D. She graduated the Bachelor of Education in biology. Her science teaching experiences is 10 years. Pim's school loading include biology and science teaching, head of science department, and head of school academic affair. Her participating Grade 9 science class includes 29 students, 18 girls and 11 boys, who their parents work as labor in Bangkok and farmer. The interesting source of energy learning in the school D is the solar power pumped water that is donated by an Australian organization.

Exploration Phase

This section describes the method of the exploration phase. The section begins with an introduction to the exploration phase, and then describes the research design in this phase. Finally, the construction of instrument, data collection and analysis will be illustrated.

1. Introduction to the Exploration Phase

The exploration phase aims to explore teacher and student idea about energy teaching and learning in order to provide information for constructing energy intervention, and enhancing teachers in the evaluation phase. This phase serves for replying:

1. What are students' existing ideas about energy and energy related technological and societal issues; and how their existing ideas inform basis ideas for developing the STS energy unit?

2. What are the participating teachers' existing ideas about energy and energy teaching and learning; and how their ideas inform basis ideas for developing the program for enhancing the STS energy teaching?

2. Instruments for Data Collection and Analysis in the First Phase

The instruments were used to explore student and teacher idea about energy conception and energy related technological and societal issues. The questionnaires, therefore, were constructed for exploring respondents' ideas. The informal conversational interviews were conducted after the respondents taking the questionnaires in order to check the accuracy respondent answers. The questionnaire will be used in this phase including (1) the Questionnaire of Student Energy Conception (QSEC); (2) the Questionnaire for Students' idea about Energy related Technological and Societal issues (QSETS); and (3) Questionnaire for Teacher Energy Perception (QTEP). Each questionnaire is clarified below.

2.1 Questionnaire of Student Energy Conception (QSEC)

This section will clarify the process of the developing the QSEC. Then, the section clarifies data collection and analysis of the QSEC. Each aspect details as below.

2.1.1 The Developing the QSEC

The questionnaire has developed including setting purpose, constructing the questions, expert panel check content validity, and piloting. Each aspect is clarified below.

(1) Setting the purpose, the QSEC was designed to explore student energy conception that related to everyday their understanding in order to provide information for meaningful energy teaching. The lay ideas of uses of energy relate to saving energy and generating power. But, in physicists' view, generating power

mainly relates to the concept of transformation, conservation and degradation of energy. To explore what the student position ideas between different two view of energy perception, the QSEC aims to explore students' understanding energy concept of conservation, transformation, and degradation. The questions were asked to explore following purposes:

Purpose 1: Students' framework of energy concept.

Purpose 2: Students understanding of energy formation.

Purpose 3: Students understanding of energy conservation

Purpose 4: Students understanding of energy transformation in generating power.

Purpose 5: Students understanding of energy transformation in electrical devices.

Purpose 6: Students understanding of energy transformation, and energy degradation

(2) Constructing the questions, the questions were constructed through the process of literature review. The questions in several energy related research (Duit, 1983; Watts, 1983; Trumper, 1993; CSTER, 1989; and Sengsook, 1997) and the questions in the physics textbook (Hobson, 1982) suggested the ideas for developing the questions of the QSEC.

(3) Experts panel check content validity, the questionnaire was checked by science teachers, scientists, and science educators. The expert gave ideas that all questions asked accurately with what the purposes were designed but some questions and choices needed to be improved.

(4) Piloting the questionnaire, the QSEC was tried out with Grade 9 students in school A early January 2004. Piloting allowed the researcher to know the time of students' completing, and how the QSEC should be improved. The data analysis revealed that some items were confused that need to be edited.

2.1.2 Data Collection and Analysis for the QSEC

The QSEC aims to explore students' framework of energy concepts, and students' existing ideas of the law of energy conservation, energy transformation and degradation. The QSEC will allow students to describe the picture about energy and situation of energy use, and give ideas to clarify terms about energy as showed in the Appendix A1. Then, given ideas in the QSEC were read through and categorized students' ideas. Students' ideas in each category will be counted and computed the percent of responses. Finally, students' ideas across four schools were compared and contrasted through the percent of each student's category description.

2.2 Questionnaire for Students' Idea about Energy Related Technological and Societal Issues (QSETS)

The QSETS is a multiple choices questionnaire. Each multiple choice question has four possible types of response; no idea; agree; disagree; individual opinion. This section will clarify the process of the developing the QSETS. Then, the section clarifies data collection and analysis of the QSETS. Each aspect details as below.

2.2.1 The Developing the QSETS

The questionnaire has developed including setting purpose, constructing the questions and choices, expert panel check content validity, and piloting. Each aspect is clarified below.

(1) Setting the purpose, the vision and goal of Thai science education were clarified the essential of energy teaching through STS. This questionnaire aims to provide information of students' ideas about energy related societal and technological issues. Under Thai science content standard and quality standard of science, the questions were asked in the following purposes

Purpose 1: Students' idea about society influences on science (energy and technology; and society and technology influences on science (energy)

Purpose 2: Students' idea about energy science influences on society and technology.

Purpose 3: Students' idea about energy knowledge influenced toward values and attitudes of energy consumption

(2) Constructing the questions and choices, the questions of the QSETS were suggested ideas from the questionnaire of Views on Science – Technology – Society (VOSTS) (Aikenhead et al., 1989; Aikenhead and Ryan, 1992). The questions were composed involving the global and specific students' country issues of energy related technology and society. The QSETS is multiple choice questionnaire that has four possible types of response including no idea, agree, disagree, and individual opinion. The process of developing the multiple aims listing holistic view of the students. The multiple choices were developed by the piloting free response questionnaire. Then, students' free response was categorized. Each student's free response category was then elaborated to develop the multiple choices.

(3) Experts panel check content validity, the questionnaire was checked by science teachers, scientists, and science educators. The expert gave ideas that all questions asked accurately with what the purposes were designed but some questions and choices needed to be improved.

(4) Piloting the multiple choice questionnaire, the QSETS was tried out with Grade 9 students in 'A' school early January 2004. Piloting allowed the researcher to know the time of students' completing, and how the QSETS should be improved. The data analysis revealed that some items were confused that need to be edited.

2.2.1 Data Collection and Analysis for the QSETS

The QSETS will be presented students to express their position ideas in each type of multiple choices including no idea, agree, and disagree as showed in Appendix A2. Then, students' position ideas will be counted and computed the percent of each response. The students' ideas of four schools, then, will be compared and contrasted.

2.3 Questionnaire for Teacher Energy Perception (QTEP)

This section will clarify the process of the developing the QTEP. Then, the section clarifies data collection and analysis of the QTEP. Each aspect details as below.

2.3.1 The Developing the QTEP

The questionnaire has developed including setting purpose, constructing the questions, expert panel check content validity, and piloting. Each aspect is clarified below.

(1) Setting the purpose, this questionnaire aims to provide information of teacher perceptions of energy conception that consists of two purposes including (1) understanding of energy transformation, conservation and degradation; and (2) applying of these energy conceptions on teaching and learning. The questions of each purpose were asked under the following framework.

Framework 1: Energy conception

1.1: Teacher perception of energy definition;

1.2: Teacher perception of the law of conservation

energy;

1.3: Teacher perceptions of degradation and conservation

energy;

1.4: teacher perceptions of energy transformation and energy degradation.

Framework 2: Teaching and learning energy

2.1 Teacher perception of goals of teaching science and energy;

2.2 Teacher perception of nature of energy conception (e.g. abstract concept, difficult concept, and so on); and

2.3 Teacher perception of factors influenced toward student energy learning

(2) Constructing the questions, the questions were constructed through the process of literature review. The questions in several energy related research (Duit, 1983; Watts, 1983; Trumper, 1993; CSTER, 1989; and Sengsook, 1997) and the questions in the physics textbook (Hobson, 1982) suggested the ideas for developing the questions of the QTPEP.

(3) Experts panel check content validity, the questionnaire was checked by science teachers, scientists, and science educators. The expert gave ideas that all questions asked accurately with what the purposes were designed but some questions and choices needed to be improved.

(4) Piloting the questionnaire, the QTPEP was tried out with the school A teacher early January 2004. Piloting allowed the researcher to know how the QTPEP should be improved. The data analysis revealed that some items were confused that need to be edited.

2.3.2. Data Collection and Analysis for the QSEC

The QTPEP will be presented teacher to give some ideas about energy teaching and learning and clarify energy concepts as showed in the Appendix A. Then, teachers' ideas will be categorized. Each teacher idea category will be

clarified and discussed to develop assumption for providing the program of enhancing the STS energy teaching.

Intervention Phase

This section describes the research method of the intervention phase. The section begins with an introduction to the intervention phase, and then describes the instrument to monitor the intervention phase will be clarified.

1. Introduction to the Second Phase

The second phase, intervention phase, is based on the findings of the first phase. The outcomes of phase one were used as a baseline and framework for designing the STS energy unit. Then the unit is initially trialled by the researcher in the school A. The research outcomes of the initial trialling will give implications for the further trialling of the STS energy unit in the evaluation phase.

The out comes of the initial trialling will be discussed into three main areas, namely; student reflections on the STS energy unit; examining student energy concept and argument which was provided by framework of a normative model for decision-making process; and using this information to provide sample lessons for a teacher to use in the energy unit. The process and outcomes of intervention phase were monitored as replying how students respond to teaching trial intervention of the STS energy unit; and what information resulting from intervention could be applied to enhance the STS energy teaching.

2. Instruments for Data Collection and Analysis in the Second Phase

The instruments were used for monitoring in two aspects including student energy learning, and student affective outcomes of energy unit. The student energy learning is student cognitive outcome and decision making about energy that was monitored by participant observation, the energy test, document analysis, and

informal conversational interview. The monitoring student affective outcomes were collected by the semantic differential scale of students' reaction in energy unit, and informal conversational interview. Next each instrument will be described about the purpose of use it, how to construct it, and how to collect and analyse data.

2.1 Participant Observation

Participant observation assists the researcher to explain the social world of the classroom and the shared meanings that are established and maintained. Advantages include the researcher being able to discern ongoing behaviour as it occurs and being able to form more intimate and informal relationships with those being observed (Cohen et al., 2000). Unstructured observations were all conducted within classroom aimed at forging a naturalistic emphasis on teachers and students in the social setting of energy STS teaching and learning. The involvement degree of researcher was the complete member. Therefore, the researcher needed to write notes after each class.

Techniques employed in participant observation include videotaping, and audio-taping. Audio-taping allows for the voices of the participants to be recorded, is less distracting and more mobile than videotaping. Group discussions are also recorded by audio-taping. Group discussion would give more information to explore students' energy concepts, critical decision making. Notes are written the thought for the initial STS energy teaching after each class. The issues and problems are also written in the notes.

2.2 Energy Test

The energy test aims to assess the development of students' energy concepts. It has developed including setting objective, constructing the questions, expert panel check content validity, and piloting. Each aspect is clarified below.

(1) Setting the objective, to assess the development of students' energy concepts, the objectives of the energy test are developed relating the principles of the intervention that have been previously clarified.

(2) Constructing the questions, the questions were constructed through the process of literature review.

(3) Experts panel check content validity, the energy test was checked by science teachers, and science educators. The experts gave ideas that all questions asked accurately with what the purposes were designed but some questions and choices needed to be improved. The experts giving opinions were computed the index objective consistency (IOC) as following formula (Pinyo-anontapong, 1984).

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

When IOC = index objective consistency;

R = sum of expert scores

N = number of experts

(4) Piloting the questionnaire, the energy test was tried out with the school A students. Piloting allowed the researcher to know how the energy test should be improved. The data analysis revealed that some items were confused that need to be edited.

2.3 Document Analysis

Students' homework was checked and interpreted their understanding of energy concepts. Students' tasks and projects were collected and interpreted their ideas. Their ideas were categorized along their value clarification and normative decision making. Then, each student's category was compared and contrasted.

2.4 Interview

An informal conversational interview is conducted without imposing any prior categorisations that may limit the field of inquiry (Fontana and Frey, 1994). The questions for an informal conversational interview emerge from the context (Best and Kahn, 1993). In the second phase of this research, the informational conversational interviews were employed for probing more student learning and affective outcomes of energy unit.

Evaluation Phase

This section describes the research method of the evaluation phase. The section begins with an introduction to the evaluation phase and then clarifies instruments, data collection and analysis.

1. Introduction to the Third Phase

The third phase, evaluation phase, aims to evaluate how the unit works through enhancing the STS energy teaching and learning. The further trialling of the STS energy unit was carried in different three schools including school B, C, and D. The program of enhancing STS energy teaching and learning was developed based on participating teachers' existing ideas. The aspects of evaluation are reflection on use the STS energy unit including students, teachers, and observer (researcher)'s reflection; examining student energy conception; and examining student argument which was provided by framework of a normative model for decision making process. The process and outcomes of evaluation phase were monitored as replying the following the research questions:

(1) How does the researcher provide the participating teachers to teach energy through STS approach?

(2) What are the affective and cognitive out comes, difficulties, and strengths for energy teaching through STS approach in the different three schools?

2. Instruments for Data Collection and Analysis in the Third Phase

Different methods of data collection were used in the evaluation phase. The instruments were used to collect reflection of the unit from the observer (researcher), teachers, and students. The instrument for observer reflections is classroom participant observation. The instrument for teacher reflections is the informal conversational interview teachers after class and during the meeting. The instruments for student reflections include the energy test, the semantic differential scale for students, document analysis, and informal conversational interview students. Next each instrument will be clarified.

2.1 Classroom Participant Observation

Participant observation assists the researcher to explain the social world of the classroom and the shared meanings that are established and maintained. Advantages include the researcher being able to discern ongoing behaviour as it occurs and being able to form more intimate and informal relationships with those being observed (Cohen et al., 2000). Unstructured observations were all conducted within classroom aimed at forging a naturalistic emphasis on teachers and students in the social setting of energy STS teaching and learning. Different degrees of researcher involvement were employed. Two role styles were used in this phase of study including peripheral member researcher and active member researcher. Peripheral membership roles are where the researcher observes and interacts closely enough with participants to establish an insider's identity without actively participating in the activities. Active membership roles may also be employed when the researcher becomes very involved with participants and the researcher becomes a participant. Often recordings are not made and notes remain unwritten until after the event.

Techniques employed in participant observation include videotaping, audio-taping, and field notes. Audio-taping allows for the voices of the participants to be recorded, is less distracting and more mobile than videotaping. Group discussions are also recorded by audio-taping. Group discussion would give more information to explore students' energy concepts, critical decision making. Field notes are flexible and unobtrusive and thought not able to record everything they produce a permanent record of events.

2.2 Document analysis

Students' tasks and projects were collected and interpreted their ideas. Their ideas were categorized along their value clarification and normative decision making. Then, each student's category was compared and contrasted.

2.3 Energy Test

The energy test aims to assess the development of students' energy concepts. Energy test has developed including setting objective, constructing the questions, expert panel check content validity, and piloting. Each aspect is previously clarified in the second phase.

2.4 The Semantic Differential Scale of Students' Reaction in Energy Unit (SSRE)

Rating scales help to convert dichotomous question, such as yes-no questions, into a multiple choice questions by using a semantic differential. A semantic differential is a variation of a rating scale which operates by putting an objective at one end of a scale and its opposite at the other. In generally, a semantic differential scales are useful in three contexts including "evaluative (e.g. value-valueless, useful-useless, good-bad); potency (e.g. large-small, weak-strong, light-heavy); activity (e.g. quick-slow, active-passive, dynamic-lethargic)" (Cohen et al., 2000: 253).

This study used the SSRE to react energy unit about (1) aspects of the unit students like and dislike; (2) students' views about the more and less interesting activity of the energy unit. Validity or creditability of questionnaire can be seen as whether respondents who complete questionnaires do so accurately and honestly. To check validity or creditability of questionnaire, it can be checked by means of the intensive interview method (Belson, 1986). Belson (1986) proposed a technique including familiarization, temporal reconstruction, probing and challenging. To interpret what respondents think accurately, therefore the interview should be used after taking the questionnaire. Students' responses in the SSRE were clarified for using with informal conversational interview with individual students and teachers.

The SSRE has developed including setting purpose, constructing the questions, expert panel check content validity, and piloting. Each aspect is clarified below.

(1) Setting the purpose, the SSRE to react the STS energy unit. These aspects include the classroom activities students like and dislike; and students' views about the more and less interesting activity of the energy unit.

(2) Constructing the questions, the questions were constructed through the process of literature review.

(3) Experts panel check content validity, the questionnaire was checked by science teachers, and science educators. The expert gave ideas that all questions asked accurately with what the purposes were designed but some questions and choices needed to be improved.

(4) Piloting the questionnaire, the SSRE was tried out with the school A teacher late September 2004. Piloting allowed the researcher to know how the QTEP should be improved. The data analysis revealed that some items were confused that need to be edited.

2.5 Interview

An informal conversational interview is conducted without imposing any prior categorisations that may limit the field of inquiry (Fontana and Frey, 1994). The questions for an informal conversational interview emerge from the context (Best and Kahn, 1993). In this research, the questions emerge from the unclear of students' and teachers' response in the questionnaire and students' behaviour in classroom.

There are the strengths of informal conversational interviews including the relevance questions can be increased immediately; interviews can be built on and emerge from the observations of the interviewer and hence the interview can be matched to individuals and circumstances (Best and Kahn, 1993). However, there are some weaknesses of informal conversational interviews including data organization and analysis could become quite difficult because of the different information collected from the interviewees for the same questions (Best and Kahn, 1993); getting the trust of the interviewee may sometimes be difficult (Spauld, 1988).

With the strength of informational conversational interviews, it is appropriate to use for probing more understanding and checking what the respondents think accurately. In the third phase of this research, the informational conversational interview were employed for probing more in order to check credibility after participants taking the questionnaires, and assess teacher reflection on the STS energy unit. The informal conversational interviews as the instrument for teacher reflections were employed after class and during the meeting. Teacher meeting allowed teachers to reach close consensus about the student learning in the STS energy.

Summary of Chapter 3

This research is conducted regarding the interpretive paradigm. The interpretive research seeks to describe and interpret human behaviour based on their natural setting rather than form laws about it (Marriam, 1998; Cohen et al., 2000). Concerning the issue of dependability, therefore, given a clear description of how data

was obtained and open acknowledge of context should be taken into account. This research enters the relationship between science, technology and society in the energy teaching and learning. The socio-cultural view was raised to interpret students' learning energy through the STS approach. The socio-cultural view suggests that the different cultures of learner and contexts should be taken into account for teaching and learning energy. Therefore, this research is designed to carry out in the different school contexts in Khon Kaen province including a school in the city, in a small town, and in a rural area. As the process of interpretation of enhancing of teaching and learning energy through STS approach, the research was designed in three phases under the paradigm of interpretive research. Three phases include the exploration, intervention, and evaluation phase. The method of interpretation has run based on the value of trustworthiness. Data collection mainly depends on questionnaire, interviews, observation, and data analysis. The interpretive researcher finds value in such techniques as thick description, audit trails, member checks, and data source triangulation.

Regarding to the three phases of the research design, data analysis and interpretation will be presented in chapters 4, 5, and 6. Chapter 4 presents the exploration of what students' ideas about energy concepts and energy related technological and societal issues, and what teachers' existing ideas of energy concepts and perception of energy teaching and learning. This chapter also concludes students and teachers ideas for further implications. Students' existing ideas were used to develop the initial STS energy unit in the intervention phase. Teachers' existing ideas were based to provide the program of enhancing the STS energy teaching. Chapter 5 reports the developing of the initial trialling of the STS energy unit; and the results of intervention that was trialled by the researcher to give implications for further trialling. Chapter 6 presents the outcomes of the further trialling in three different schools. This chapter also discussed the issues for further research.

CHAPTER IV

EXPLORATION PHASE

The exploration phase involved exploration students' and teachers' ideas in four different schools including school A, B, C, and D. Exploring students' ideas involves ideas about energy concepts and energy related technological and societal issues. The school B, C, and D teachers' ideas were explored to discover their understanding of energy concepts and perception of energy teaching and learning. Then, a range of students' and teachers' ideas were analyzed to be possible implications for teaching and learning based on the STS approach in next research phase. First, students' ideas about energy concepts and energy related technological and societal issues will be discussed. Then, teachers' existing ideas of energy concepts and perception of energy teaching and learning will be clarified. Finally, students' existing ideas are discussed to guide baseline to develop the initial STS energy unit. And, teachers' ideas are discussed as baseline to provide program of enhancing the STS energy teaching.

Student Existing Ideas about Energy Concept

Discussing energy concepts include definition of energy, the law of energy conservation, energy transformation and degradation. Student energy ideas about energy concepts include students' framework of energy concept; student existing ideas of energy formation; student existing ideas of the law of energy conservation; student existing ideas of energy transformation in generating power and electrical devices; and student existing ideas of energy degradation. Then, students' existing ideas about these energy concepts were concluded. Each is presented as below.

1. Student Framework of Energy Concept

Students were asked to use the word ‘energy’ to write 3 short sentences. These sentences reflected what framework of energy concept to exist in students. Their statements can be categorized into six categories of student energy concept.

First, in the category of the natural occurrence, students concerned with natural occurrence of energy in things and living things. They wrote statements that showed existing energy in living things and things. The examples of student sentences were categorized in this category including:

- “Energy is the important thing for life”;
- “If the world did not have energy, it would mean no life”
- “Energy is thing that we can use for working”;
- “My body wants to use energy 1000 calories a day”;
- “We got energy when we ate rice”;
- “Working out affect to burning energy in my body”;
- “Living thing have energy”;

In the category of energy saving, student sentences related to saving energy, worthy energy use, or to appreciation of the value of energy. The examples of student sentences were categorized in the theme of saving energy including:

- “We should save energy because it is continually decrease”;
- “Energy is valuable and useful thing”;
- “We should worthily use energy”
- “60 million Thai should be decease energy use”

In the category of sources of energy, students concerned with sources of energy. Their sentences were written relating to energy source (e.g. sun, water, and battery). The examples of student sentences related to energy source including:

- “The sun energy was used in solar cell”;

“The power plant use water energy to generate electric”;

“I played toy until the battery was gone”;

“Used coal produces pollution”;

“I used wind energy”;

“Fuel can be made energy”;

In the category of types of energy, student sentences were written to related forms of energy. Some students did not write sentence relate energy; they just wrote down form of energy such as “heat”, “electricity”, and “mechanical energy”. Student sentences were categorized in this framework, for examples:

“Energy consists of many forms”;

“Energy consists of many forms such as electric energy, body energy, etc.”;

“I can see everything because of light energy”;

“My Television consumes electric energy”;

In the category of energy transformation, students concerned with energy transformation. Their sentences were written which related to the concept of transformation energy. The examples of student sentences were categorized in this framework including:

“Energy is never lost but changes other energy”;

“The power plant changes water energy into electric energy”

“Electrical energy cause of glowing”;

“Does mechanical energy change to electrical energy?”

“Energy cannot be destroyed or created, it just transforms into another kind of energy”

In the category of mechanical use of energy, student wrote sentences related to the mechanical process. The examples of student sentences were categorized in this framework including:

“People use machine energy in the factories”;

“Moving is mechanical energy”;

“If we no have energy, we cannot do work”;

“Energy make thing move”

Students’ ideas in each category were counted frequency and computed into percentages shown in Table 4.1. According to Table 4.1, students’ framework of energy concept mainly falls in the category of natural occurrence, energy saving, and sources of energy. It could be said that fundamental student framework of energy concept involved natural occurrence of energy in things and living things; energy saving and appreciation of the value of energy; and perceiving energy through sources of energy.

Table 4.1 Students’ Frameworks of Energy Concept

Category	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Natural occurrence	14	20.6	38	46.9	52	38.8	25	32.0	129	35.7
Energy saving	15	22.0	18	22.2	36	26.9	3	3.9	72	20.0
Sources of energy	15	22.0	1	1.3	18	13.4	5	6.4	39	10.8
Types of energy	8	11.8	9	11.1	12	9.0	14	17.9	43	11.9
Energy transformation	8	11.8	9	11.1	9	6.7	19	24.4	45	12.5
Mechanical use of energy	8	11.8	6	7.4	7	5.2	12	15.4	33	9.1
Total	68	100.0	81	100.0	134	100.0	78	100.0	361	100.0

These findings suggest that energy teaching might start from sources of energy, natural occurrence of energy in things and living things, and issues of energy saving. These must give ideas and knowledge about phenomena and experiences that students bring to the classroom that may help them further understand the nature of energy. Interestingly, school D students might easily gain their understanding of the nature of energy. Many of them presented the concept of transformation energy as categorized in the category of energy transformation.

2. Student Existing Ideas of Energy Forms

Students were asked to give energy forms. Forms of energy were given approximately sixty percent of their respondents (See Table 4.2). Their given forms

of energy showed that they knew some forms of energy. The well known forms of energy among four school students include electric, heat, light and mechanical energy. However, approximately forty percent of the respondents presented the sources of energy. These indicated that they were confused between forms and sources of energy. Interestingly, it seems that the sun is a fundamental idea of energy form among four schools. Water was popular recognized as energy form among School A and School B students. School C students were mainly confused fuel as energy form. The machines and electrical devices were most confused for school D students.

Table 4.2 Students' Identifying of Energy Forms

Category		School A		School B		School C		School D		Grand Total	
		f	%	f	%	f	%	f	%	f	%
Forms of energy	Electric	21	11.9	29	17.6	40	13.9	16	8.0	106	12.8
	Heat	20	11.3	15	9.1	27	9.4	21	10.6	83	10.0
	Mechanical	18	10.2	16	9.5	22	7.6	20	10.1	76	9.2
	Voice	13	7.4	7	4.2	15	5.2	18	9.1	53	6.4
	Light	10	5.7	10	6.1	21	7.3	17	8.5	58	7.0
	Kinetic	7	4.0	5	3.1	15	5.2	1	0.6	28	3.4
	Nuclear	5	2.8	4	2.4	5	1.7	7	3.5	21	2.5
	Potential	5	2.8	15	9.1	7	2.4	0	0.0	27	3.3
	Chemical potential	3	1.7	11	6.7	8	2.9	9	4.5	31	3.7
Electromagnetic	1	0.5	1	0.6	0	0.0	0	0.0	2	0.2	
Sum of forms of energy		103	58.3	113	68.4	160	55.6	109	54.9	485	58.5
Sources of energy	Water	21	11.9	13	7.9	20	6.9	10	5.0	64	7.7
	Sun	15	8.5	10	6.1	25	8.7	12	6.0	62	7.5
	Fuel	10	5.7	11	6.7	48	16.7	7	3.5	76	9.2
	Wind	10	5.7	3	1.8	8	2.8	13	6.5	34	4.1
	Living things	7	4.0	1	0.6	1	0.3	1	7.0	23	2.8
	Machine / Electric devices	4	2.4	5	3.1	0	0.0	27	13.6	36	4.4
	Heat underground	1	0.5	1	0.6	0	0.0	3	1.5	5	0.6
	Magnetic	1	0.5	0	0.0	0	0.0	0	0.0	1	0.1
	Mass	1	0.5	0	0.0	1	0.3	0	0.0	2	0.2
	Natural	1	0.5	0	0.0	0	0.0	0	0.0	1	0.1
	Radioactive	1	0.5	0	0.0	0	0.0	0	0.0	1	0.1
	Vapor	1	0.5	0	0.0	18	6.3	0	0.0	19	2.3
	Wave	1	0.5	3	1.8	0	0.0	0	0.0	4	0.5
Food	0	0.0	2	1.2	2	0.7	0	0.0	4	0.5	
Mineral	0	0.0	0	0.0	5	1.7	0	0.0	5	0.6	
Dry cell / battery	0	0.0	3	1.8	0	0.0	4	2.0	7	0.8	
Sum of sources of energy		74	41.7	52	31.6	128	44.4	90	45.1	344	41.5
Total		177	100	165	100	288	100	199	100	829	100

3. Students' Existing Ideas of the Law of Energy Conservation

The QSEC gave students four situations that two represent concept of the law of energy conservation and other two represent idea of energy saving. Students were asked to select which two choices represent the concept of the law of conservation energy. The findings in Table 4.3 revealed that approximately eighty percent of respondents across four schools selected situation (a) and (c). Situation (a) and (c) represent the idea of energy saving. This seems that students perceived the law of energy conservation as energy saving.

Table 4.3 Students' Respondents about Situations of the Law of Energy Conservation

Which two of the four following situations are examples of law of energy conservation?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) Dum has changed the incandescent bulbs to energy-saving fluorescent tubes. He has found them cheaper in the long run as they last longer and they are much brighter.	19	33.9	19	25.3	39	41.0	16	45.7	93	35.6
(b) Ann touches the back of a fan. She found that it is hot. So, she understands that input energy (electric energy) has been transformed into kinetic energy of the fan and heat energy in the motor.	0	0.0	6	8.0	3	3.2	3	8.6	12	4.6
(c) Daeng's family switch off the lights and all electrical points when no one is in the room, such as television and the computer, before going to the bed every night. Leaving them on stand by mode will still use up energy.	30	53.6	36	48	47	49.5	15	42.6	128	49.1
(d) The officer of the Num-pong steam power plant explains to students that the power plant uses high pressure steam at 500 C° as the force for turning the turbine. The turbine then turns the electric generator. This process provides electricity, but it is not 100 percent of input energy. The remaining input energy is transformed in to thermal energy of the low pressure water and heat of the turbine.	7	12.5	14	18.7	6	6.3	1	2.8	28	10.7
	56	100	75	100	95	100	35	100	261	100

To verify what students' ideas about the law of energy conservation, students were probed more "what do you understand by the law of energy conservation?". Students' descriptions could be categorized into four categories including saving of energy sources, storing up or preserving energy, worthy energy use, and concept of energy transformation.

In the category of saving energy sources, the law of energy conservation was perceived as saving energy source. Examples of student responses include:

“It means energy saving”;

“It is saving energy for using in long run”;

“It means that do not use wastefully energy”; and so on.

In the category of preserving energy, the law of energy conservation was perceived as storing up or preserving energy. Examples of student responses include:

“It is like preserve energy”;

“Conservation of energy is storage and preserving energy”;

“It is storage for next generation”; and so on.

In the category of appreciation of the energy value, the law of energy conservation was perceived as use worthily energy or appreciation of the value of energy. The examples of student responses include:

“Conservation of energy means that understand to use effectively value of energy”;

“It is use energy to gain the most advantage”

“I think conservation energy is the smart usage of energy and no wastage of it”

Table 4.4 Students’ Description Framework of the Law of Conservation Energy

Category	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Saving of energy sources	21	50.0	22	48.9	22	33.3	13	39.4	78	41.9
Preserving energy	10	23.8	3	6.7	17	25.8	11	33.3	41	22.1
Appreciation of energy value	11	26.2	20	44.4	26	39.4	9	27.3	66	35.5
Energy transformation	0	0.0	0	0.0	1	1.5	0	0.0	1	0.5
Total	42	100	45	100	66	100	33	100	186	100

In the category of energy transformation, students used concept of energy transformation to describe the law of energy conservation. Example: “energy doesn’t disappear, it just changed”.

The law of energy conservation is stated that total energy of an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same (Hobson, 1982). It has just only one student to give description in this sense. Table 4.4 shows that almost everyone given descriptions was saving of energy sources, storing up energy, and worthy energy use. These reflect that student experience might affect scientific concepts because term of conserving (in Thai ‘A-nu-rak’) is also used in everyday language. ‘A-nu-rak’ is viewed as preserving, storing up or saving. This confusion might be generated readily socialized understandable, for example, the government campaigned for saving energy as the Project Energy Divide By Two, that the terms saving and conservation are interchangeable in common usage. Students may perceive the law of energy conservation as same as meaning of conserving in everyday language. This showed the similar western findings. Kirkwood (1988) and Trumper (1991) reported that the law of energy conservation was understood as saving of fuel or energy sources.

4 Student Existing Ideas of Energy Transformation

This part will discuss students’ descriptions of energy transformation that occurs in the process of hydro power plant and electrical devices (i.e. blender, television, and lamp). The diagram of a hydro power plant operation; pictures of a blender, a television, and a lamp were shown before asking the students to write descriptions of energy transformation in them. Data analysis revealed that students’ descriptions may be categorized into three frameworks of descriptions including event, one step of energy transforming, and multi-step of energy transforming. Framework of event, student described the event of showing diagrams and pictures. They also gave the products of energy use. They did not give concept of process of energy changing forms. In the framework of one step, students described changing energy in

one step. Process of one step description can be seen as one to one and one to several forms of energy. In the framework of multi-step, students gave description of changing energy forms step by step to the last form of energy. Students' description frameworks for each diagram or picture are discussed below.

4.1 Energy Transformation in a Process of Generating Power

Students described what energy transformation occur in the process of generating power from the hydro power plant. Three frameworks of students' descriptions were considered. Statistic of students' descriptions was showed in Table 4.5.

In the framework of event, students described what happened in the hydro power plant. They gave electricity and current as the products of dam. Their descriptions did not give concept of process of energy changing forms. Examples of students' descriptions include:

“Electricity”;

“Dam produces electricity”;

“Electricity is contributed to our houses”;

In the framework of one step, given descriptions of energy transformation in hydro power plant appears as one to another one form of energy. Students' descriptions resulted into two categories of changing forms of energy including category A, changing water energy into electric energy; and category B, changing mechanical energy into electric energy.

In the framework of multi-step, students gave step by step of energy transforming from water or potential energy to electric energy in a hydro power plant. Students' descriptions come out into two categories. Category C, students' descriptions involve transforming water or potential energy into mechanical energy and, then, into electric energy. Category D, students' descriptions showed ideas of

water or potential energy to transform into mechanical energy, heat energy, and then electric energy.

Table 4.5 Students' descriptions of Energy Transformation

Framework	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Event	5	17.9	4	10.0	6	12.5	5	18.5	20	14.0
One step – A	7	25.0	9	22.5	36	75.0	6	22.2	58	40.5
One step – B	6	21.4	12	30.0	0	0.0	3	11.1	21	14.7
Multi-step – C	9	32.1	15	37.5	4	8.3	13	48.2	41	28.7
Multi-step – D	1	3.6	0	0.0	2	4.2	0	0.0	3	2.1
Total	28	100.0	40	100.0	48	100.0	27	100.0	143	100.0

According to Table 4.5, the majority of students across four schools held concept of energy transformation that approximately ninety percent of them gave descriptions in the framework of the one step and the multi-step. Approximately ninety percent of school B and C, and eighty percent of school A and D students' descriptions concerned with energy could be converted from one form to others. However, students' description framework of one step was more used than the multi-step. Approximately eighty percent of school C, fifty percent of school A and B, and thirty percent of school D student described energy transform through framework of one step. Given description of one step framework suggests that a number of them consider only changing of energy from one to another obvious useful or observable form of energy (i.e. category A and B). This seems that they only understand ideal concept of energy transformation. Interestingly, the majority of school D students describe energy transformation through framework of multi-step. There is also a number of the school A and B students that employ framework of multi-step, but few of school C students do. Unfortunately, a few students recognized heat spreading out during giving description step by step. Identifying heat as appearing in students' description of category D may support students to easily understand the concept of the law of energy conservation. Recognizing heat spreading out might give students to make sense why people need to save energy although scientific knowledge is stated that the total amount of energy stays the same.

4.2 Energy Transformation in Electrical devices

Students described what energy transformation occur in electrical devices. The pictures of a blender, a television, and a lamp were showed to elicit students' description of energy transformation. Three frameworks of students' descriptions were considered including event, one step, and multi-step. Students' descriptions of energy transformation in each electrical device are discussed below.

4.2.1 Energy Transformation in Blender

Students' descriptions of energy transformation in blender across four schools resulted into two description frameworks including event and one step. Statistics of students' descriptions are showed in Table 4.6.

Table 4.6 Students' descriptions of Energy Transformation in the Blender

Framework	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Event	31	86.1	12	30.0	26	54.1	11	39.3	80	52.6
One step – A	5	13.9	28	28.0	16	33.3	17	60.7	66	43.4
One step – B	0	0.0	0	0.0	3	6.3	0	0.0	3	2.0
One step – C	0	0.0	0	0.0	3	6.3	0	0.0	3	2.0
Total	36	100.0	40	100.0	48	100.0	28	100.0	152	100.0

In the framework of event, students described what happened when the blender was working. They described what and how the fruit and ice was changing; and what electricity produced. Examples of students' descriptions include:

“It grinded the fruit”;

“Electric produce fruit juice”;

“It is changed from solid to liquid”;

“Electric energy changes into the juice”;

“Fruit turn into liquid”;

In the framework of one step, given descriptions of energy transformation in a blender appears as one to another form of energy. Students' descriptions resulted into three categories of changing forms of energy including category A, changing of electric energy to kinetic or mechanical energy; category B, changing of heat to sound energy; and category C, changing of mechanical energy into heat.

The results in the Table 4.6 indicate that students seem to find it difficult to describe energy transformation in a blender. A majority of students' description frameworks of event appear across four schools, in particular school A and C. Students' ideas of changing forms of energy in a blender only concerned with describing the framework of one step. Main students' description of energy transformation was in category A that involved changing of electric energy to kinetic or mechanical energy. This indicates that students' descriptions emphasized on obvious energy transformation. However, school C students gave several description pathways of energy transformation in blender. Other two pathways were clarified including changing of heat into energy and from mechanical energy into heat. The school C students gave various ideas. If they have a chance to discuss energy transformation in a blender, they may generate several forms of energy that are converted.

4.2.2 Energy Transformation in a Television

Students' descriptions of energy transformation in a television across four schools resulted into two description frameworks into event and one step. The process of one step description could be seen as one to one and one to several forms of energy. Statistics of students' descriptions are showed in Table 4.7.

In the framework of event, students described what happened when a television was working. They described what was produced when electricity flew into television such as electric energy, mechanical energy, and communication energy. Examples of students' descriptions include:

“Electricity makes television working, so then we can watch television”;

“Electricity produces pictures”;

“Wave becomes picture”;

“Electric energy was used”;

In the framework of one step (one to one), given descriptions of energy transformation in a television appears as one form of energy to another.

Students’ descriptions resulted into five categories including:

Category A, electric energy changes into light energy;

Category B, electric energy changes into voice energy;

Category C, electric energy changes into picture energy;

Category D, electric energy changes into mechanical energy;

Category E, mechanical changes into heat, light or electric energy.

Framework of one step (one to several), given descriptions of energy transformation in a television appears as one to several forms of energy in one step.

Students’ descriptions resulted into two categories including category F, changing of electric energy to light and voice energy; and category G, changing of electric energy to light, heat, and voice energy.

Table 4.7 Students’ descriptions of Energy Transformation in Television

Framework	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Event	31	86.1	13	32.5	22	46.8	11	39.3	77	51.0
One to one – A	2	5.6	2	5.0	1	2.1	0	0.0	5	3.3
One to one – B	2	5.6	6	15.0	1	2.1	17	60.7	26	17.2
One to one – C	0	0.0	0	0.0	4	8.6	0	0.0	4	2.6
One to one – D	0	0.0	9	22.5	1	2.1	0	0.0	10	6.7
One to one – E	0	0.0	2	5.0	2	4.3	0	0.0	4	2.6
One to several – F	1	2.7	8	20.0	15	31.9	0	0.0	24	15.9
One to several – G	0	0.0	0	0.0	1	2.1	0	0.0	1	0.7
Total	36	100.0	40	100.0	47	100.0	28	100.0	151	100.0

Again, students found it difficult to describe energy transformation in electric devices. According to Table 4.7, the majority of student across four schools

described energy transformation in television through framework of event. However, there were number of students that expressed their existing ideas about energy transformation. This could be seen as giving description in the framework of the one step and the multi-step. Framework of one step (one to one) was more employed than one to several for school B and D students. The school D students prefer description involving changing of electric energy to voice energy. Unlike, school B students emphasized on a description that electric energy changed into voice; and electric energy changed into mechanical energy. There is a number of description framework of one step (one to several) appears in school B and C students. Main description is changing of electric energy to light and voice energy. Given only obvious forms of energy suggests that students might have difficulties to clarify forms of energy in television. Only one student across four schools recognized non-useful form of energy (i.e. heat in category D) that is converted in the television. It seems that the modest use of the framework of one step might block their thinking of several forms of energy.

4.2.3 Energy Transformation in Lamp

Students' descriptions of energy transformation in a lamp across four schools resulted into two description frameworks into event and one step. Process of one step description could be seen as one to one and one to several forms of energy. Statistic of students' descriptions was showed in Table 4.8.

Framework of event, students described what happened and what products resulted into when electricity flew into the lamp. Given products include electric, light, and mechanical energy. Examples of student given events include:

- “Electric energy is used to glow the lamp”;
- “Changing electricity from dam to the lamp”;
- “Inside wire make it glowing”;

In the framework of one step (one to one), given descriptions of energy transformation in a lamp appears as one form of energy to another. Students' descriptions resulted into five categories including:

Category A, electric energy changes into light energy;

Category B, electric energy changes into heat;

Category C, heat changes into light energy;

Category D, chemical energy changes into electric energy;

Category E, mechanical changes into heat, light or electric energy.

Framework of one step (one to several), given descriptions of energy transformation in a lamp appears as one form of energy to several in one step. Students' descriptions resulted into two categories including category F, changing of electric energy to heat and light energy; and category G, changing of electric energy to heat, and mechanical energy of the light.

Table 4.8 Students' descriptions of Energy Transformation in Lamp

Framework	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
Event	24	66.7	13	32.5	14	29.8	9	32.1	60	39.7
One to one – A	12	33.3	17	42.5	28	59.6	19	67.9	76	50.3
One to one – B	0	0.0	2	5.0	1	2.1	0	0.0	3	2.0
One to one – C	0	0.0	0	0.0	2	4.3	0	0.0	2	1.3
One to one – D	0	0.0	1	2.5	0	0.0	0	0.0	1	0.7
One to one – E	0	0.0	6	15.0	0	0.0	0	0.0	6	4.0
One to several – F	0	0.0	1	2.5	1	2.1	0	0.0	2	1.3
One to several – G	0	0.0	0	0.0	1	2.1	0	0.0	1	0.7
Total	36	100.0	40	100.0	47	100.0	28	100.0	151	100.0

According to Table 4.8, the majority of students held description framework of the one step of energy transformation. The most common description across four schools is category A that involves changing electric energy into light energy. This suggests that obvious forms of energy obstruct their generating several forms of energy in lamp. Interestingly, school B and C students gave various description pathways of energy transformation. This seems that they indicated different points of energy transforming, for examples, transforming of chemical

energy to electric energy occur at the pole of battery; and transforming of electric energy to heat and light energy occur at the wire of the lamp. If students are advised to describe energy transformation step by step, they might give several forms of conversion. However, it was different in the school A. The majority of school A student described energy transformation in lamp through framework of event.

5. Student Existing Ideas of Energy Degradation

Understanding of energy degradation may support learning in other energy concepts (Duit, 1983). Energy degradation is the simple concept of entropy (Duit & Haeussler, 1994). Entropy is energy concept that looks at the second law of thermodynamic from the atomic point of view. The second law of thermodynamic is stated that it is impossible, within an isolated system, to transform all the system's thermal energy into non-thermal forms of energy. Using the concepts of thermal energy and temperature, entropy is given the meaning of the concept of disorganization. The disorganization in the isolated systems can easily become more disorganized, but those systems can become more organized only with outside assistance (Hobson, 1982). As the simple concept of entropy, therefore, the concept of energy degradation involves the processes taking place in closed systems where the amount of energy does not change; but the usefulness of energy inevitably declines and is hard to reverse to become more useful energy (Duit & Haeussler, 1994). This part explores simple students' ideas of energy degradation. Student existing ideas will be discussed below including spreading out of energy and being hard to become more useful energy.

5.1 Heat Spreading Out in Lamp Energy Transformation

Students were asked about a lamp using electrical energy if the amount of light energy produced was more than, less than, or the same as the amount of electrical energy used. Interestingly, the majority of school B students thought that the light energy lamp produced was less than electrical energy used (see Table 4.10). School B students might be aware of other forms of energy besides light energy. This

seems that spreading out of energy might be concerned. However, data analysis in Table 4.9 – 4.12 showed that the majority of school A (61.30%), C (37.50%), and D (51.85%) students, with thought that light energy lamp produced was the same as electrical energy used. It suggests that they might not recognize spreading out of energy or heat as no useful energy.

It is not surprise why the majority of students thought that the amount of light energy the lamp produced was the same as the amount of electrical energy used when considering their description of energy transformation. Data analysis found that students' descriptions resulted into nine categories. The majority of students' ideas across four schools fell down in category A – electric change into light energy (See in Table 4.9 - 4.12). Eight categories of students' descriptions include:

- Category N, students did not give any ideas or replied that they did not know, for examples, “electric energy flow to lamp”; “lamp is glowd because wire link to dry cell”; “something is changing in lamp”, and so on.
- Category A, the description involves electric changing into light energy. Some students, for example, described that electrical energy was used for glowing the lamp.
- Category B, the description involves electric changing into light energy and heat.
- Category C, the description involves chemical potential energy (or identifying battery) changing into light energy and / or heat.
- Category D, the description involves chemical potential energy (or identifying battery) changing into electrical and heat energy.
- Category E, the description involves heat of battery changing into electrical energy and light.
- Category F, the description involves fuel changing into light.
- Category G, the description involves mechanical changing into light, heat energy and / or electric energy.

The description of energy transformation can give ideas of energy degradation as spreading out form of energy or non-useful heat. For example; chemical potential energy (or identifying battery) changing into electrical energy in battery, then heat losing to surrounding or heat used for warming up the lamp, and finally transforming into light energy. However, this did not completely appear in students' descriptions. Interestingly, majority of School B students thought that light energy lamp produced less than amount of electrical energy used. Their descriptions of energy transformation might show some ideas of usefulness of energy declines or spreading out of energy. Unfortunately, few of their descriptions were categorized in category C that seems to recognize spreading out of heat.

Table 4.9 School A Student's Categories of Description Used the Power in a Lamp

Category	Not reply		Same as		Less than		More than		Total	
	Res.	%	Res.	%	Res.	%	Res.	%	Res.	%
N	0	0.00	0	0.00	3	9.67	1	3.23	4	12.90
A	0	0.00	11	35.50	2	6.44	1	3.23	14	45.17
B	0	0.00	4	12.90	1	3.23	0	0	5	16.13
C	0	0.00	1	3.23	2	6.44	1	3.23	4	12.90
D	0	0.00	1	3.23	1	3.23	0	0	2	6.46
E	0	0.00	0	0.00	0	0	0	0	0	0.00
F	0	0.00	0	0.00	0	0	0	0	0	0.00
G	0	0.00	2	6.44	0	0	0	0	2	6.44
Total	0	0.00	19	61.30	9	29.01	3	9.69	31	100.00

Table 4.10 School B Student's Categories of Description Used the Power in a Lamp

Category	Not reply		Same as		Less than		More than		Total	
	Res.	%	Res.	%	Res.	%	Res.	%	Res.	%
N	1	2.50	2	5.00	8	20.00	1	2.50	12	30.00
A	0	0.00	3	7.50	4	10.00	6	15.00	13	32.50
B	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C	0	0.00	1	2.50	4	10.00	1	2.50	6	15.00
D	0	0.00	1	2.50	2	5.00	0	0.00	3	7.50
E	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
F	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
G	0	0.00	2	5.00	0	0.00	4	10.00	6	15.00
Total	1	2.50	9	22.50	18	45.00	12	30.00	40	100.00

Table 4.11 School C Student's Categories of Description Used the Power in a Lamp

Category	Not reply		Same as		Less than		More than		Total	
	Res.	%	Res.	%	Res.	%	Res.	%	Res.	%
N	1	2.08	2	4.17	0	0.00	1	2.08	4	8.33
A	3	6.25	12	25.00	5	10.42	6	12.50	26	54.17
B	0	0.00	1	2.08	2	4.17	0	0.00	3	6.25
C	1	2.08	0	0.00	2	4.17	0	0.00	3	6.25
D	0	0.00	2	4.17	1	2.08	2	4.17	5	10.42
E	0	0.00	1	2.08	3	6.25	0	0.00	4	8.33
F	0	0.00	0	0.00	3	6.25	0	0.00	3	6.25
G	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	5	10.41	18	37.50	16	33.34	9	18.75	48	100.00

Table 4.12 School D Student's Categories of Description Used the Power in a Lamp

Category	Not reply		Same as		Less than		More than		Total	
	Res.	%	Res.	%	Res.	%	Res.	%	Res.	%
N	2	7.41	3	11.11	1	3.70	2	7.41	8	29.63
A	2	7.41	5	18.25	2	7.41	1	3.70	10	37.04
B	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
D	0	0.00	1	3.70	1	0.00	0	0.00	2	3.70
E	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
F	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
G	2	7.41	5	18.52	0	0.00	0	0.00	7	25.93
Total	6	22.23	14	51.85	4	14.81	3	11.11	27	100.00

Additionally, half of their reason was in category N which did not show even a concept of energy transformation (see Table 4.10). Consider across four schools. There are some ideas of energy spreading out. Heat was recognized as spreading out when students gave descriptions of energy transformation in category B, C and D. Table 4.9 showed that approximately thirty percent of School A students given description was in category B and C. Table 4.10 showed that fifteen percent of School B students given description were in category C. Table 4.11 showed that approximately twelve percent of School C students given description were in category B and C. Table 4.12 showed that approximately four percent of School D students given descriptions were in category D.

5.2 Given Energy Degradation as a Reason of Energy Saving

Disagreement of energy saving and the law of energy conservation were raised to explore students' ideas about relationship between energy use and scientific knowledge. Students were asked the question of why people try to save energy while scientific knowledge is stated that the total amount of energy is always constant. Students' descriptions come up in various reasons. Their ideas could be categorized into five categories.

In the category of limited energy sources, given student reasons concerned limited existing energy sources. For example:

“Some energy is limited”;

“Energy is limited but people are continually increased”;

“Even though we have amount of energy source, it might run out in the future”.

Table 4.13 Student Reasons of Necessary of Energy Saving

Category	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
1.Limited energy sources	19	67.8	25	62.5	26	54.2	14	51.9	84	58.7
2.Difficulties of generating power	1	3.6	2	5.0	1	2.1	0	0.0	4	2.8
3.Money saving	4	14.3	5	12.5	0	0.0	3	11.1	12	8.4
4.Hard to reusing energy	4	14.3	0	0.0	13	27.1	4	14.8	21	14.7
5.Environment conserving	0	0.0	1	2.5	5	10.4	5	18.5	11	7.7
6.Losing energy	0	0.0	2	5.0	3	6.2	1	3.7	6	4.2
No reply	0	0.0	5	12.5	0	0.0	0	0.0	5	3.5
Total	28	100.0	40	100.0	48	100.0	27	100.0	143	100.0

In the category of difficulties of generating power, students considered the difficulties of the process of generating power.

In the category of money saving, students thought that energy saving is money saving and gaining profit. For example:

“Saving electricity is saving money”;

“Saving energy support government to gain national profit”;

“Generating power is transforming energy for use ... we have to pay...”.

In the category of difficulties of reusing energy, students gave some ideas concerning with difficulties to reuse energy sources. For example:

“Energy will be gone when we use it and cannot reuse it”;

“Energy is used... it cannot be generated as soon”.

In the category of environment conserving, students’ reasons involve the effect on environment. Students thought that we needed to save energy because it would be decrease environment damages.

In the category of losing energy, students concerned with losing energy into another form or non-useful forms of energy. Energy transformation is a cause of losing useful forms of energy. Examples of student responses include:

“Energy change into another forms, we cannot use energy in everyday life”;

“When we used energy it always lost”.

According to Table 4.13, the majority of students across four schools thought that people need to save energy because energy sources are limited. This suggests that student fundamental ideas focus with restriction of useful energy forms. Student reasons of money saving, difficulties of reuse energy, and environment conserving were moderately given. Money saving appear in school A, B, and D students’ ideas. Environment conserving was moderately concerned by school C and D students. Category of difficulties of reuse energy was recognized by school A, C and D students. Reasons of losing useful energy and difficulties of generating power appeared rarely across four schools.

Consider student existing ideas of energy degradation. The concept of energy degradation involves the processes taking place in closed systems where the

amount of energy does not change; but the usefulness of energy inevitably declines and is hard to reverse to become more useful energy. Given ideas of difficulties of reusing energy and difficulties of generating power could be said that students were aware of difficulty to reverse to become useful energy. Additionally, given idea of losing of energy suggests that students might concern with usefulness of energy to declines. Interestingly; the categories of difficulties of reuse energy, difficulties of generating power, and losing of energy appear across four schools although there is not a number of these ideas. School C students may be the easiest to develop their understanding of energy degradation because their ideas of these categories amount to nearly forty percent of responses.

6. Conclusion of the Students' Existing Ideas about Energy

The findings of students' ideas about energy were clarified as following:

(1) Students' framework of energy concepts, the findings revealed that students' framework of energy concept mainly falls in category of natural occurrence, energy saving, and sources of energy. It could be said that fundamental student framework of energy concept involved natural occurrence of energy things and living things; energy saving and appreciation of the value of energy; and perceiving energy through sources of energy.

(2) Students' existing ideas about energy forms and sources, the findings revealed that given forms of energy showed students' energy forms known. The well known forms of energy among four school students include electric, heat, light and mechanical energy. However, they were confused between forms and sources of energy. Interestingly, it seems that the sun is fundamental idea of energy form among four schools. Water was popularly recognized as energy form among School A and School B students. School C students were mainly confused fuel as energy form. The machine and electrical devices were most confused for School D students.

(3) Students' ideas about the law of energy conservation, the findings revealed that students' giving description the term involved the saving of energy sources, storing up energy, and worthy energy use. These reflect that student experience might affect scientific concepts because term of conserving (in Thai 'A-nu-rak') is also used in everyday language. 'A-nu-rak' is viewed as preserving, storing up or saving. This confusion might be generated readily socialized understandable, for example, the government campaigned for saving energy as the Project Energy Divide By Two, that the terms saving and conservation are interchangeable in common usage. Students may perceive the law of energy conservation as meaning of conserving in everyday language.

(4) Students' existing ideas about energy transformation, the findings revealed that the giving description of energy transformation mostly considered only changing of energy from one to another obvious useful or observable form of energy. This seems that they only understand ideal concept of energy transformation.

(5) Students' existing ideas about energy degradation, the findings revealed that students held slightly ideas of energy spreading. Heat was recognized as spreading out when student given description of energy transformation. Given ideas of difficulties of reuse energy and difficulties of generating power could be said that students were aware of difficulty to reverse to become useful energy. Additionally, given idea of losing of energy suggests that students might concern with usefulness of energy to decline. Interestingly; the categories of difficulties of reuse energy, difficulties of generating power, and losing of energy appear across four schools although there is not a number of these ideas.

Student Existing Ideas about Energy Related Technological and Societal Issues

Students' ideas about energy related to technological and societal issues will be clarified into three dimensions including 1) students' ideas about technological and societal aspects influencing on the study of energy; 2) students' idea about the study of energy influencing on technology and society; and 3) students' values influencing

on energy consumption. This part will clarify each dimension of students' ideas and then conclude students' existing ideas about energy related technological and societal issues.

1. Students' ideas about Technological and Societal Aspects Influences on the Study of Energy

This part will discuss what students' ideas about systems, design and volition of application scientific and other knowledge (e.g. philosophical, sociological, political, economic, humanistic aspects and so on) will be expressed when students are asked to make decision about the study of energy with balancing issues of political effects, and adopting knowledge and technology from other countries.

The majority of students across four schools thought that government should give research money to scientists to study sustainable energy or explore the unknowns of energy resources. Statistical detail of their responses is showed in Table B1.1, Appendix B. It seems that the fundamental given idea across four schools concerns with gaining knowledge for country development. They did not want to see Thailand fall behind other countries. The other ideas that were given amount of response percentages including satisfying scientific curiosity for school A students, and giving all research although it cannot tell ahead whether will be beneficial or not for school C students.

When students were asked the relationship between country's politics and studying of energy, the majority of students across four schools agreed with a country's politics to affect scientists' study of energy. Statistical detail of their responses is showed in Table B1.2, Appendix B. According to Table B1.2, students agreed with politics to affects scientists' study of energy because of three main reasons including lobby funding, government policy that be able to force scientists to work, and scientist trying to help society. The fundamental students' ideas across four schools involve scientists have to lobby for funding from government. Therefore, government could control what scientists should do. A number of school C and D

students thought that governments could force scientists to work on a project which scientists feel was wrong. A number of school B students concerned with scientists involving society because scientists understood and tried to help society.

The necessary of study of energy is one of issues to probe students' ideas about technological and societal aspects influences on the study of energy. The issue of adopting knowledge and technology from other countries instead of studying the research related to energy was raised. The majority of students across four schools disagreed with no need to study research related to energy (see Table B1.3, Appendix B). Students across four schools concerned more with development of scientist quality, and development of technology from local requirements. They might think that developing scientist quality is still important in Thailand because of supporting industrial development. They might be given this idea through media and government advertising that "Thailand will be the new industrial country (NIC)". However, it seems that students have a little concerning with economic aspects. Only school B and C students concerned more with reason of the balance between import and export trade.

Above findings showed that students had difficulties to understand the relationship between politic and energy study. Students across four schools took the country development into account for decision making of need to study energy. They perceived that their country needed to be more developed. Government can finish this job because they can give amount of funding for scientific study and tell what scientists should do. It seemed that the issue of country development supported their ideas to realize to study energy and other scientific knowledge in Thailand. Study scientific research might help develop quality of scientists that foster sustainability of the country development rather than to adopt technology and scientific knowledge from other countries.

2. Students' Ideas about Energy Influenced on Issues Related Technological and Societal Aspects

This part discusses students' ideas of scientific knowledge (energy) to influence system, design, and volition of application scientific and other knowledge (e.g. philosophical, sociological, political, economic, humanistic aspects and so on). Students were asked the issues of use of energy to make decision related technological and societal aspects.

When students had to consider the use of a large amount of sunlight everyday a year in Thailand, the majority of students across four schools agreed with ideas of developing their knowledge of solar cell technology which could be used to build solar power plant (See Table B1.4, Appendix B). Fundamental ideas for given reasons seem to be economic aspects. The majority of student reasons across four schools concerned with worthiness in the long run because solar energy has no cost. Other interesting students' ideas include concerning with preparing for next generation energy use, and property of solar energy. There are a number of students across four schools to concern with the use amount of energy in the future, and property of solar energy as sustainable energy.

Students were asked to give opinions to agree or disagree with the decision to close down the coal power plants that have polluted the air. The majority of school A, B, and C students disagreed with no producing electricity from the coal power plant (see Table B1.5, Appendix B). They held a strong belief of scientific endeavor. Disagreement reasons of students across four schools concerned with the ideas that scientists could create process of coal generating power to emit less pollution. Additionally, a number of them thought that government needs decision making based on economic growth. This illustrates that they held the issue of country development based for decision making again. Students' ideas of emitting less pollution of generating and economic growth might receive from their parents and government advertising. Thai government policy wishes to be a developed country. Government is showing the advertisements of safety and worth of coal power plant; and

information of rising Thailand's GDP. These students' ideas reflected what their decision making related to Thailand situation. However, it seems that students also concerned with environment damage. Only school D students agreed with no producing electricity from the coal power plant. The majority of them concerned with coal power plant may add problem of pollution, and pollution should be confined as much as possible. Additionally, there were a number of students across four schools to express their idea that pollution should be confined because spreading it would create more damage.

When students were asked whether scientists and engineers should be the ones to decide what types of energy their country will use in the future; a number of students expressed both agreement and disagreement (see Table B1.6, Appendix B). The majority of school B and C students disagreed because they concerned more with equally decision making between scientists, engineers, other specialists, and the informed public. This suggests that school B and C students might have strongly democrat point of view and emphasize with validated and reliable knowledge through social process. The majority of school A and D students agreed with this issue because they concerned with more have a better understanding facts and issues; therefore, they should be the ones who decide what types of energy Thailand will use in the future. Interestingly, a number of students across four schools also concerned with scientist and engineer decisions because of their better understanding. This suggests that students believed in expert decision rather than public decision.

When students were asked the relationship between understanding about science and technology and moral decision, the majority of students across four schools agreed that understanding about energy could help people to make some moral decision about generating power (see Table B1.7, Appendix B). It seems that students understand that environment issues relate to moral decision making and application of science and technology. Fundamental students' ideas across four schools expressed that information background of effect in the environment could help people cope with the moral aspects of environment. However, many students thought that there was no relationship between understanding of science and

technology, and moral decision. There are a number of students across four schools to perceive that science and technology had nothing to do with moral decision.

Students were asked to give opinion about whether science (energy) and technology offer a great deal of help in resolving social problems (e.g. controversy between consuming electric energy, worried about pollution, and using land). The majority of students across four schools agreed with helping of science and technology to resolve social problems (See Table B1.8, Appendix B). It seems that school A and D students strongly believe in scientific application to solve social problems. There were number of them concerned with that new innovations could be used for solving social problem. Unlike, school B and D students seemed to be not sure that science and technology was able to help solving all social problems.

Across students' responses of question 4 – 8 showed what their position ideas of influence of scientific (energy) knowledge toward application scientific and other knowledge for resolving social problems. Interestingly, school B and C students concerned with that science (energy) and technology was not able to help solving all social problems. They perceived that the better understanding of scientific (energy) knowledge is not key idea of resolving the use energy. This was clarified because they strongly concerning with public decision making.

However, overview of students across four schools students held strongly belief of scientific endeavor. Issue of country development supports them to use scientific knowledge resolving social problems. New innovation of energy could be used for solving social problems of the use energy. For example, scientists could create the process of coal generating power to emit less pollution. Based on their strongly believed in scientific knowledge, they preferred to respect decision of people who have better understanding of energy for decision making of energy use. Their ideas seem to be general Thai because Thai aware authority. Children are usually taught that good children must obey their parents, teachers and adults who have better understanding (Titthummo, 2004). This view is shown in the proverb about obeying adults, 'Phu yai arb nam ron ma kon' or 'dern tam phu yai ma mai kad' (Adults see

the world before children, so children should obey them). It might be said that this view holds the Thai people to everywhere. In the science classroom, Hongladarom (2002) argued that learning science tend to lack discussion because students might believe that good students usually do not say anything that might oppose what the teacher is teaching. In work place, Thai workers follow what their head orders without disputing or negotiating the best way for their organization.

3. Students' Values Influences on Energy Consumption

This part will discuss students' values, norms and beliefs of society that will be reflected from their negotiation, validity and interpretation of data through the social processes. Issues of energy consumption might extract what students' ideas of application scientific (energy) and other knowledge which are socialized by values and norms. Below are students' ideas when students are asked the issues of managing energy saving, constructing more power plants, and people using too much energy.

When students were asked about the help of scientific (energy) knowledge and technology to manage energy saving; the majority of both groups of students agreed that knowledge could help (see Table B1.9, Appendix B). Students concerned with two main energy concepts to help manage energy saving including the law of energy conservation, and energy degradation. The majority of students across four schools thought that our knowing of "energy cannot be lost and destroyed but it is transformed into useful form" helped to save energy. Interestingly, that term is definition of energy that usually appears in the textbooks. It might be said that they replied like that because they were familiar with it. However, there are a number of students across four schools who replied "when energy is used; it will be transformed into less useful and hard to reuse form". This could be assumed that students concerned with reason of degradation energy to support people to save energy.

When students were asked whether construct more power stations or not, there was the different main opinion between four school students. According to Table B1.10 in Appendix B, the majority of school A and D students agreed with

construction more power plants but the majority of school C students disagreed. School B students expressed a number of opinion both agreement and disagreement. However, data show that fundamental students' ideas across four schools involve reserving energy for future use and energy saving. These two ideas expressed both agreement and disagreement for construction more power plants. There are a number of students across four schools to agree with construction more because of reserving energy for future use. There are also a number of students across four schools to disagree with construction more because people should save energy rather than plan to construct new power plant. Students ideas of reserving energy for future use and energy saving reflect that they may perceive demand and supply of Thailand energy consumption. In fact, Thailand has less production of electric energy per person than the developed countries (Nation master, 2004).

When students were asked about people energy using; the majority of students across four schools agreed that people use too much energy (see Table B1.11, Appendix B). A Fundamental students' idea across four schools involve difficulty of generating energy. Students thought that people use too much energy because they did not concerned with how the difficulty generating energy. This reflects that students held scientific idea to value human behavior of use energy. They may thought that if people know how difficult to produce organized form of energy for use, people will use worthily energy. This students' idea is similar to the scientific idea of entropy that relate to concept of disorganization.

Across the three questions, issues of energy saving extracted what students' value and norm of energy consumption. Students usually concern with issues of country development. Their values were based on concerning with increasingly use energy in the future because of industrial country. Therefore, students' idea of energy saving was established because of concerning with storing up energy for future use. This reflects that environment setting, belief, society, and culture situate them into distinguish normative decision making ideas. Additionally, they thought that scientific (energy) knowledge may support people to become aware of energy saving.

This idea was clarified because of their concerned with the difficulty of generating energy that relate to concept of disorganization.

4. Conclusion of Students' Existing Ideas about Energy Related Technological and Societal Issues

The findings of students' ideas about energy related technological and societal issues can be concluded as follows:

(1) Students' ideas about technological and societal aspects influences on the study of energy, the findings revealed that students across four schools took the country development into account to decision making of need to study of energy. They perceived that their country needed to be more developed.

(2) Students' ideas about energy influenced on issues related technological and societal aspects, the findings revealed that students across four schools students held strongly belief of scientific endeavor. Issue of country development supports them to use scientific knowledge resolving social problem. New innovation of energy could be used for solving social problems of the use energy. Based on their strongly believed in scientific knowledge, they preferred to respect decision of people who have better understanding of energy for decision making of use energy. Their ideas seem to be general Thai because Thai aware authority. Children are usually taught that good children must obey parents, teachers and adults who have better understanding (Titthummo, 2004).

(3) Students' values influences on energy consumption, the findings revealed that students usually concern with issues of country development. Their values were based on concerning with an increasing in energy use in the future because of industrial country. Therefore, students' idea of energy saving was established because of concerning with storing up energy for future use. This reflects that environment setting, beliefs, society, and culture situate them into distinguish normative decision making ideas.

Teacher Existing Ideas

Effective teaching requires teachers who hold an understanding of what is to be learned and what is to be taught. Shulman (1987) suggested that teachers needed to build a knowledge base for teaching. His framework includes knowledge of content, general pedagogy, curriculum, pedagogy content, learners, educational contexts and educational ends. Exploring three teachers' existing ideas about energy and energy teaching and learning may give information for providing of the program for enhancing the STS energy teaching. Each aspect is discussed below.

1. Teachers' Existing Ideas of Energy Concepts

Teachers' existing ideas about framework of energy concept, the law of energy conservation, energy transformation and degradation are discussed below.

1.1 Teacher Framework of Energy Concept

Teachers were asked to give students the fundamental concepts of energy for eliminating student confusion of what energy was. All the teachers thought that giving examples of energy forms and sources, and energy use in electrical devices would eliminate student confusion. They argued that these descriptions also would easily develop student understanding of energy because it closed to student everyday life.

School C teacher Ann viewed light and sound energy; and using energy in electrical devices as concrete thing to help student to generate understanding of energy. As Ann stated:

Teachers should give students over view meaning of energy, and then give them easier understanding form of energy such as light energy. Light energy helps us to see everything. We have comfortable life because we use electrical energy to a number of electrical devices (e.g. refrigerators). Sound energy

is also concrete thing because talking is sound energy. We can hear what our talking. (Ann)

School B teacher Kunya and school D teacher Pim concerned with giving energy sources that related to student everyday life such as food, electrical devices, and energy in environment. They perceived that this had to give student fundamental concepts of energy. As they stated:

Give students examples of electrical devices in their houses.

Give students energy sources that related surviving in everyday life. (Kunya)

I emphasize energy sources that appear in everyday life such as food. Students have already learned existing energy in food during Grade 8 learning. Energy in surrounding environment and electrical devices should also be described.

(Pim)

Above discussed teachers' existing ideas indicated that teachers hold the framework description of energy concept as energy sources and forms of energy. This is consistent with students' existing ideas.

1.2 Teacher Existing Ideas of the Law of Energy Conservation

Teachers were asked how and what the definition of “the law of energy conservation” should be described. Teachers' responses are separated into two ideas. These include energy conserving or saving, and idea of energy transformation. Each is presented below.

(1) Ideas of energy conserving or saving, the law of energy conservation is seen as energy conserving or saving. This is a view resembling the majority of students' ideas of the law of energy conservation that has previously been presented. Ann perceived the law of energy conservation as the laws for conserving energy. She stated that:

I may tell students what those laws consist of and what students should do under those laws of energy conservation. Generally, these laws usually are stated including use energy to gain high advantage and appreciate value of energy, and how people can conserve energy. (Ann)

Kunya viewed the law of energy conservation as energy saving that concerned with wise using energy and gaining the highest profit of energy use. She proposed that teaching energy related social concerned forms of energy; it would enhance students this view. As Kunya stated:

The law of energy conservation is wisely use of energy and gain the highest profit as much as you can. I must teach forms of energy which were known by students and related currently society and technology. (Kunya)

(2) Ideas of energy transformation, teachers mentioned the concept of energy transformation to give description of the law of energy conservation. Kunya thought that energy transformation should be taught. Pim argued that the concept of energy transformation should be given students instead of the term of the law of energy conservation that did not appear in Grade 9 student textbooks. Kunya and Pim stated:

Teach forms of energy which can be transformed into another forms. (Kunya)
We cannot find term of the law of energy conservation in the Grade 9 student textbooks. Anyway, we gave students “Energy cannot be lost but it can be transformed” and examples of energy transformation. (Pim)

This teachers’ idea indicated that teachers understood concept of the law of energy conservation. The law of energy conservation stated that total energy of an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same (Hobson, 1982).

1.3 Teacher Existing Ideas of Energy Transformation

Teachers were asked to give the main energy transformation in the process of generating power in a hydro power station that should be learned by Grade 9 students. Teachers' existing ideas are separated into two categories. These include framework description of the one step of energy transformation and the multi-step.

Ann held the framework description of the one step of energy transformation. She would describe students the transforming of gravitational potential energy (water energy) into electric energy. She would like to present students the instructional media for how electric energy was produced from water power rather than to describe the concept of energy transformation. As Ann stated that:

I will make the very small hydro power station to demonstrate how it generates electricity. This demonstration will also give students the idea that electric energy is produced from water power. Water power is mechanical energy. (Ann)

Kunya and Pim held the framework description of the multi-step of energy transformation. They would describe that hydro power station energy transforms from mechanical energy into heat, chemical, light, voice, and electric energy. As Kunya and Pim stated that:

Teach students mechanical, heat, chemical, and electric energy that are converted in hydro power station. This follows the law of constant energy. (Kunya)

Electric energy is converted from other forms of energy such as heat, light, mechanical, and voice energy. (Pim)

Identifying heat and other forms of energy spreading out during description as step by step may support Kunya and Pim to foster students' understanding of the law of energy conservation and energy degradation.

1.4 Teacher Existing Ideas of Energy Degradation

Teachers were asked how they should explain about why people need to save energy. Teachers' existing ideas could be categorized into four categories. These include describing origin of sources energy, giving advantage and disadvantage of energy use, giving idea of energy transformation, and describing the difficulties of generating power. Each is presented below.

(1) Describing origin of energy sources, teachers would describe origin of petroleum and other sources of energy. Teachers thought that if they described taking a great duration of time the origins petroleum and other sources of energy, it would give students' reasons why people need to save energy. As Kunya and Pim stated:

I will describe the origin of petroleum. Petroleum originated as the bodies of dead marine and other animals which were buried in soil over million years. Concerning with taking the long time of originated petroleum, energy will run out if we did not save energy. (Pim)

I will teach the origin of energy sources that related to surviving. (Kunya)

(2) Teachers thought that giving advantage and disadvantage of energy use could suggest students why people need to save energy. Teachers would present forms of energy and how they are useful for life. As Ann and Kunya stated:

I will give students forms of energy and maintaining of life need using energy. Various ways of application energy will also present. Students must know how to use worthily energy. (Ann)

I will tell students the advantage and disadvantage of energy. Then, the method of energy saving will be advised to students. (Kunya)

(3) Difficulties of generating power, teacher described that the process of generating electric energy consume amount of the budget. She thought that this idea might remind students to save energy. As Ann stated that:

Energy use needs to concern with generating electricity. Government has to pay a huge budget for a power plant. In a power plant, we have to employ many machines to generate electricity. According to this, we have to save energy. (Ann)

(4) Concept of energy transformation, Kunya thought that giving idea of transforming energy would suggest student to conserve energy. She might concern with the usefulness of energy to be decreased. Kunya stated that:

The law of energy stated that energy cannot be created or destroyed; energy can be transformed from one form to another. With this concept, students should save energy. (Kunya)

Consider teacher existing ideas of energy degradation. Given concept of energy transformation could indicate that they concern with usefulness of energy to declines. Additionally, given ideas of difficulties of generating power and origin of sources suggest that teacher concerns the concept that energy is hard to reverse to become more useful energy. These two ideas indicate that teachers hold some ideas of energy degradation. These teachers might be easily suggested to foster students to develop the understanding of energy degradation.

2. Teachers' Existing Ideas of Energy Teaching and Learning

Three aspects were evident in teachers' ideas regarding the teaching and learning of energy. First, teachers concerned with energy teaching and learning for application energy concepts in everyday life. Second, teachers believe that energy teaching should engage in students' experiences. Third, teachers want to manage instruction that empower students to be able to think, act, and solve problems of

energy concept by themselves. Below illustrate each aspect of teachers' existing ideas.

2.1 Energy Teaching and Learning for Applications in Everyday Life

As a means of eliciting teachers' ideas about important outcomes for the energy teaching and learning; teachers were asked about their goals for energy teaching. The fundamental idea of these three teachers was the teaching and learning energy that foster student to apply energy concepts in everyday life. This idea is consistent with Thailand's goal of science education (IPST, 2002). Teachers' ideas of application expressed the two aspects including energy use, and solving problems which consequent using energy.

Teachers thought that energy teaching should foster students to consider the gaining the highest profit of energy use and the strategies of energy saving. As Ann and Pim stated:

I think that the important goal of energy teaching is supporting students to concerns how energy is important to life. I will illustrate advantage of each form of energy when it is used. Then, I will foster students to think how we can gain a high profit of energy use and how we can save energy to use in long run. (Ann)

I think that the important thing is allowing students to know how they can conserve energy and how worthy use energy. (Pim)

Kunya emphasized application of energy concepts in everyday life as solving problems which are consequent in using energy. As Kunya stated:

I will support students to apply knowledge in everyday life. Energy teaching have to foster student to work cooperate in group. In working group, they are assigned to thinking of solving problems that consequent using energy. (Kunya)

2.2 Engaging in Students' Experiences

All teachers concerned that the important aspects of teaching in being able to enhance students' understanding of energy concepts was teaching energy related to students' experiences. For example, Ann thought that students could easily make sense if they learned what they knew in their communities. As she stated that:

Students' experiences related to what they did in their communities. I think that this might be important because it relates to their everyday life. Students will easily understand science learning. Learning knowledge that close to students' experiences support students to have a good remembering about it.
(Ann)

Kunya and Pim disagreed that the energy was difficult concept. They thought that energy related student everyday experiences. Therefore, everyone have to easily make sense about energy. As Kunya and Pim stated:

I disagree because people use energy for surviving. Everyone must understand what energy is and how people use worthily energy. (Kunya)

I disagree because maintaining life, people need energy. Energy relevant what we do in everyday life, therefore people have to what energy is. (Pim)

Ann agreed that energy was difficult concept. She concerned that energy was an abstract concept. Ann thought that if she gave forms of energy that related to students' everyday experiences, students would perceive energy in concrete way of thinking. As Ann stated:

I viewed energy as abstract concept but I usually give students forms of energy that they know, for example, light. Light allow us to be able see everything. Electric energy, even we cannot see it, we can know it when we are using electrical devices. (Ann)

2.3 Empowering Students to be able to Think, Act, and Solve Problems

Teachers concerned that the important aspects of energy teaching in being able to accomplish the goal of science education was empowering students to think, act, and solve problems. They perceived that today students lack of critical thinking and are lazy to think. Empowering students to think and solve problems helps students to generate more understanding. As Pim stated:

The importance thing of science learning is thinking skill. Students have to plan how they will do experiments. Planning allow students to develop thinking skills. Thinking support the development of the brain, therefore, students can generate more understanding. (Pim)

Kunya concerned that teaching has to allow student to work cooperate in group. She thought that students' working in group will empower students to generate their thinking and problem solving skills. As Kunya stated:

Presently, we don't students to learn alone. They have to learn in group Energy teaching have to foster student to work cooperate in group. Working group, students can develop thinking and problem solving skills. (Kunya)

The above three aspects of teachers' existing ideas could be clarified that they perceived the goal of science education (IPST, 2002). However, it seems that teachers might be difficult to act according to what they think. Teachers may rely on the National Test and the information in a textbook for teaching science. They thought that giving more lecture was what students and their parents want because it support students' examination. There is not enough time to teach for application and fostering students' solving problems because there is a certain amount of content that has to be covered within a semester. As Ann and Kunya stated:

Doing activities, students have to spend more time. I have to teach all content in this book. My students will take the National Test in the next two months. (Ann)

Some students would like to be given lecture and exercise of the National Test rather than science activities. They thought that the exercises helped them getting the higher scores. (Kunya)

3. Conclusions of Teachers' Existing Ideas

Teachers' existing ideas of energy concepts and perception of energy teaching and learning were clarified. Each aspect is clarified as below.

The findings of Teachers' existing ideas of energy concepts were clarified as following conclusions:

(1) Teachers' existing ideas about energy forms and sources, the findings revealed that teachers held the framework description of energy concept as energy sources and forms of energy. This is consistent with students' existing ideas.

(2) Teachers' existing ideas about the law of energy conservation, the findings revealed that their description of the term was expressed into two ideas including energy conserving or saving, and idea of energy transformation.

(3) Teachers' existing ideas about energy transformation, the findings revealed that they held the framework description of the one step of energy transformation and the multi-step. Ann held the framework description of the one step of energy transformation. Kunya and Pim held the framework description of the multi-step of energy transformation.

(4) Teachers' existing ideas about energy degradation, the findings revealed that giving description of energy transformation concerning with the usefulness of energy to declines. Additionally, given ideas of difficulties of generating power and

origin of sources suggest that teacher concerns the concept that energy was hard to reverse to become more useful energy. These two ideas indicate that teachers hold some ideas of energy degradation.

The findings of teachers' perception of energy teaching and learning revealed that they concerned with three aspects. These include:

- (1) Energy teaching and learning for application energy concepts in everyday life;
- (2) Engaging in Students' Experiences; and
- (3) Empowering Students to be able to Think, Act, and Solve Problems.

Implications for Energy Teaching and Learning

Above students' ideas about energy concepts and energy related technological and societal issues; and Teachers' existing ideas of energy concepts and perception of energy teaching and learning suggested ideas of the STS energy teaching and learning. Two aspects of implications were discussed including:

- Baseline to develop the STS Energy Unit;
- Baseline to provide program of enhancing the STS energy teaching

1. Baseline to Develop the STS Energy Unit

Sociocultural views of science learning promote the community aspect of classroom and the role of peer discussion in assisting students to learn science. In order to enhance students' conceptual development, the unit should allow students to learn about how their existing ideas are debated and tested until a consensus decision with classroom community exists that similar to scientist community. The STS Energy unit should be constructed corresponding with student existing ideas. Baselines from student existing ideas include ideas about energy and energy related technological and societal issues that are discussed below.

1.1 Suggested by Student Existing Ideas about Energy

From the students' ideas about energy, the findings suggest aspects of constructing the unit. These include starting the unit with sources of energy, natural occurrence of energy in things and living things, and issues of energy saving; distinguishing between energy sources and forms; placing of electric energy and sun as core content; catching up the process of generating power and a trip to a power plant; enhancing students' description of energy transformation to concern with converting to several forms of energy; and enhancing perception of relationships between the law of energy conservation, energy transformation and degradation. Each aspect is discussed below.

(1) Starting with sources of energy, natural occurrence of energy in things and living things, and issues of energy saving. Fundamental student framework of energy concept involves natural occurrence of energy things and living things; energy saving and appreciation of the value of energy; and perceiving energy through sources of energy. These findings suggest that energy teaching might be started from sources of energy, natural occurrence of energy in things and living things, and issues of energy saving. These must give ideas and knowledge about phenomena and experiences that students bring to the classroom may help them further understand the nature of energy.

(2) Distinguishing between energy sources and forms. It seems that students were confused between forms and sources of energy. Energy teaching in four schools needs to distinguish between forms and sources of energy.

(3) Placing of electric energy and sun as core content. Electric energy is the most well known form of energy among four schools. The sun as source of energy is fundamentally viewed as energy form among four schools. It might help students to further link to concepts of energy, if electric energy and sun are placed as core content of this group student energy unit.

(4) Catching up the process of generating power and a trip to a power plant. Students' ideas of difficulties of reuse energy, difficulties of generating power, and losing of energy were given for reasons of energy saving to appear across four schools although there was a few of them. It might be said that their existing ideas close to concept of energy degradation. Enhancing student understanding of energy degradation may eliminate student understood of saving energy as the law of energy conservation. Energy teaching may allow students to catch up the process of generating power because students may see how hard it is to produce useful forms of energy or becoming more organized energy.

(5) Enhancing students' description of energy transformation to concern with converting to several forms of energy. The findings revealed that the majority of students employ description framework of one step. This reflected that they only understood an ideal concept of energy transformation. It seems that description framework of multi-step of energy transformation allows students to recognize spreading out of energy. The spreading out of energy could be linked to student understanding of the law of energy conservation and energy degradation. Energy teaching may enhance students' description of energy transformation as step by step. For example, the energy transformation in a hydro power plant may be described as step by step including (1) potential energy of water transforming into mechanical or kinetic energy of rotating turbine and waste heat in turbine; (2) mechanical of turbine transforming into electric energy and heat in generator; and (3) electric energy transforming into heat in wire on the process of distribution electric energy. Given description of energy transformation in electrical device should be enhanced to concern with converting to several forms of energy. Framework of multi-step might allow students to recognize them. Given description of a blender might be clarified as, for example, blender change electric energy to kinetic energy and then sound energy; or electric energy to kinetic energy and heat, and then sound energy.

(6) Enhancing perception of relationships between the law of energy conservation, energy transformation and degradation. As discussed above, the concepts of energy conservation, transformation, degradation support to each other for

easily making sense to students. Energy degradation helps student to more easily understand energy conservation because it provides an answer to why there is less output as electrical energy in process of generating power than the input as potential, mechanical, or thermal energy. The concept of energy conservation helps to explain more about the energy transformation. For example, electric energy is used when mixing orange juice in a blender. Where does this energy go? It must go into warming the juice. A lot of it goes into warming the motor, also, as evidenced by the heat of the blender near the motor. The laws of energy conservation state that the amount of electric energy lost equals the amount of kinetic energy and thermal energy gained (Hobson, 1982).

1.2 Suggestions by Students' ideas about Energy Related to Technological and Societal Issues

From the students' ideas about energy related to technological and societal issues, the findings suggest aspects of constructing the unit. These include proposing activities of decision making between energy use for public concern, and other constraints; empowering students to negotiate and dispute scientific knowledge related to social issues; enhancing students' perception of social aspects of politics; and balancing scientific knowledge and technological and societal aspects. Each aspect is discussed below.

(1) Proposing activities of decision making between energy use, public concern, and other constraints. Students strongly believe that efficiency of scientific application can solve social problems. It seemed that the issue of country development supported their ideas to realize to study energy and other scientific knowledge in Thailand. Their values were based on concerning with increasingly using energy in the future because of industrial country. The activities of decision-making between the energy consumption; and limitation of generating power and other constraints might enhance student technological thinking.

(2) Empowering students to negotiate and dispute scientific knowledge related to social issues. Based on their strong belief in scientific knowledge, they preferred to respect decision of people who have better understanding of energy for decision making of energy use. Students' perception of a decision depending only on experts was not equivalent with the nature of scientific knowledge. Scientific knowledge is generated and validated throughout scientific community (Ziman, 1978; Driver et al., 1994a). The STS energy learning will empower students to negotiate and dispute scientific knowledge for shaping ideas and finding scientific solutions. The energy classroom should be run as a scientific community.

(3) Enhancing student perception of social aspects of politics. It seemed that the students had difficulty giving an opinion that identified the relationship between social aspects (e.g. politics) and energy study. The STS energy unit might enhance the perception of the relationship between energy and social aspects of politics.

(4) Balance scientific knowledge and technological and societal aspects. The goal of Thai science education is for students to perceive the interplay between science, technology, human kind and the environment in order to take care of the environment; and develop the characteristics of the scientific habit of mind (IPST, 2002). Student's ideas showed that they are more concerned with scientific endeavor than environment conservation. The balance between scientific knowledge and technological and societal aspects through the STS energy unit will foster students' perceptions of interplay between science, technology, human kind and environment.

2. Baseline to Provide Program of Enhancing the STS Energy Teaching

Findings indicated that participating teachers slightly understood energy concepts. They only viewed energy as the energy sources and forms. Some of the participating teachers understood the law of energy conservation in a sense of energy conserving or saving. All the teachers only recognized the ideal concepts of energy transformation that shown in their description of one step of energy transformation.

There are a few teachers' ideas that could be clarified for existing ideas of energy degradation as mentioning of energy spreading out and difficulties of reversing to more useful energy. These teachers' ideas about energy concepts are consistent with students' ideas.

Overview of teachers' existing ideas of energy teaching and learning could be clarified that participating teachers perceived the idea of constructivist learning. These could be viewed because teachers gave ideas about engaging in students' experiences; empowering students to be able to think, act, and solve problems; and application of energy concepts related to student everyday experiences. However, findings revealed that teachers relied on teaching of energy content which supported taking test of students. They thought that there was not enough time to teach for application and fostering students' solving problems. This might reduce teachers' action according their existing ideas. It seems to be difficult for participating teachers to blend content of energy and pedagogy for enhancing student understanding of energy and application of energy. The Thailand science curriculum does not only aim to enhance student understanding of science content but also its application. Energy teaching should allow developing student understanding of energy concept, decision making, and take action for resolving societal issues related energy and technological aspects.

The above discussion is consistent with Shulman's argument that teachers need to develop content knowledge and pedagogical knowledge (Shulman, 1987). Because the teachers held a little understanding of energy concepts, tutoring of energy concepts should be given. As consistency of teachers' ideas and students' ideas about energy concepts, and concerning with Thai culture about teacher (e.g. teacher is respected person; teacher should not be insulted about knowledge); tutoring of energy concept may be conducted beginning with teacher group discussion to consider and develop students' ideas of energy. Then scientific ideas of energy will be discussed after considering students' ideas of energy. To enhance teachers to develop student understanding of energy concept, decision making, and take action for resolving societal issues related energy and technological aspects; they should be provided the

workshop on learning theories and the STS approach. They also should be supported working in classroom to reflect them for gradually gaining development of energy teaching based on the STS approach.

Summary of Chapter 4

The exploration phase aimed to explore students' existing ideas about energy concepts and energy related technological and societal issues, and teachers' existing ideas about energy and perception of energy teaching and learning. This chapter reported students' and teachers' existing ideas, and then discussed to give implications for developing the STS energy unit and the program for enhancing the STS energy teaching in the Khon Kaen province, Thailand. Each aspect is highlighted as below.

The findings of school A, B, C, and D students' existing ideas about energy concepts and energy related technological and societal issues were discussed to suggest baseline for developing the STS energy unit in the intervention phase. These findings suggest interesting assumptions for developing the STS energy unit. Regarding the students' existing ideas, the unit should start with sources of energy, natural occurrence of energy things and living in things, and issues of energy saving; placed the electric energy and sun as core content. The unit should give chance students to distinguish between energy sources and forms; and enhance student description of energy transformation to concern with converting to several forms of energy, and the relationship between the law of energy conservation, energy transformation and degradation. The unit also proposes activities of decision making between energy use, public concern, and other constraints; empowering students' perception of social aspects of politics; and enhances students' perception of social aspects of politics. These assumptions are employed for the developing the STS energy that is illustrated in Chapter 5.

The findings of school B, C, and D teachers' existing ideas about energy and perception of energy teaching and learning were discussed for the baseline of the

developing the program of enhancing the STS energy teaching. The findings of teachers' existing ideas about energy concepts indicated that the participating teachers slightly understood energy concepts. Their perception of energy teaching and learning regarded empowering students to be able to think, act, and solve problems; and application of energy concepts related to student everyday experiences. However, it seems to be difficult to obtain their perception. This seemed to be difficult for participating teachers to blend content of energy and pedagogy for enhancing students' understanding of energy and application of energy. To enhance teachers to develop students' understanding of energy concept, decision making, and taking action for resolving societal issues related energy and technological aspects; therefore, they should be provide the workshop of learning theories and the STS approach. The program of enhancing the STS energy teaching should also enter the illustration of energy concepts. These assumptions were applied for enhancing the STS energy teaching and learning in three different schools, Khon Kaen province that could be seen in Chapter 6.

CHAPTER V

INTERVENTION PHASE

The intervention phase involves the developing the initial STS energy unit and then trialing this unit by the researcher in the school A. The unit was developed based on students' ideas about energy and energy related technological and societal issues that were reported in chapter four. This chapter reports the designing the initial STS energy unit and the outcomes of the initial STS energy intervention to give implications for enhancing the STS energy teaching in the Evaluation phase. Each aspect is clarified in the following sections.

Designing the Initial STS Energy Unit

The initial STS energy unit was developed based on the students' existing ideas about energy and energy related technological and societal issues. Designing the unit could be viewed through clarifying the assumption about students' ideas, developing objectives of the intervention, and structure of initial STS energy teaching. Each aspect is clarified below.

1. Assumptions about Student' Ideas

Assumptions about the use of STS approach for teaching and learning energy were made based on student ideas about energy, and energy related technological and societal issues. The assumptions were discussed as energy conceptions; and energy conceptions related technological and societal issues that detailed in topic of "Implications for Teaching and Learning", in chapter four. Assumptions for energy teaching are:

- Starting with sources of energy, natural occurrence of energy in things and living things, and issues of energy saving;
- Distinguishing between energy sources and forms;

- Placing of electric energy and sun as core content;
- Catching up the process of generating power and trip of the power plant;
- Enhancing student description of energy transformation to concern with converting to several forms of energy;
 - Enhancing perception of relationships between the law of energy conservation, energy transformation and degradation;
 - Proposing activities of decision making between energy use, public concern, and other constraints;
 - Empowering students to negotiate and dispute scientific knowledge related to social issues;
 - Enhancing student perception of social aspects of politics;
 - Balancing scientific knowledge and technological and societal aspects.

2. Objectives of intervention

The objectives of intervention were constructed under the framework of goals of Thai science education, science content standards and learning outcomes of energy for Grade 9 students (see detail in Chapter two); and the assumptions about students' ideas about energy related technological and societal issues. According to these regarding, the principles of the intervention could be drawn as following. By the end of the interventions, students can:

1. Explain the meaning of energy formations such as gravitational potential, chemical potential, kinetic, mechanical energy, heat and so on.
2. Identify the difference between energy formations and energy resources.
3. Explain concepts of energy conservation, transformation, and degradation.
4. Describe energy transformation in electrical devices by concerning with the concept of energy degradation.
5. Describe energy transformation in the process of generation power by concerning the concept of energy degradation.
6. Explain energy conservation in electrical devices by concerning the concept of energy degradation.

7. Explain energy conservation in the process of generation power by concerning the concept of energy degradation.
8. Apply energy degradation to give reasons of saving energy.
9. Gain their ability of decision-making about the energy consumption by concerning with technological and societal aspects (e.g. limitation of generating power; condition of economic, social, personal, and environmental needs; and other constraints).
10. Gain their perceptions of relationship between energy and social aspects (e.g. politics, economic, value and belief, and so on).
11. Negotiate and dispute scientific knowledge (energy) to shape ideas and find scientific solution for energy related societal issues.
12. Gain their perceptions of interplay between science (energy), technology, human kind, and environment.
13. Gain their values and attitudes for energy saving by concerning with energy degradation, economic aspects, environment issues, and others.

3. The Structure of Initial STS Energy Teaching

The initial STS energy unit was developed based on the assumptions regarding students' existing ideas about energy, and energy related technological and societal issues; and under emphasized to bring the relationship between science, technology, and society into learning energy. The framework of teaching the STS energy unit consists of five stages:

- (1) Identification of social issues stage,
- (2) Identification of potential solutions stage,
- (3) Need for knowledge stage,
- (4) Decision-making stage, and
- (5) Socialization stage.

The initial STS energy unit consists of three sub-units including 1) using energy in Thailand, 2) energy resources and energy formations, and 3) generation power. Classroom activities were outlines for the sub-units which were arranged into a unit of work as shown in Table 5.1.

Table 5.1 Outline for the Initial STS Energy Teaching Activities

Sub-units	Objectives	Issues	Activities
1. Use energy in Thailand (three sessions)	1, 2, 10, 11	Are there different sources of energy which we use energy to do work for us? Should Thai government give research money to scientists to study alternative energy or explore the unknown of energy resources?	<p><u>Identification of social issues stage:</u></p> <ul style="list-style-type: none"> • Group discussion to solve the problem of oil embargo affect to Thailand. <p><u>Identification of potential solution stage:</u></p> <ul style="list-style-type: none"> • Group discussion to think of the possible alternative energy • Present student group ideas <p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Brain storming to give and classify sources of energy. • Group discussion of alternative energy. • Present renewable energy (e.g. solar power, geothermal energy, tidal power, wind power, biomass, and energy from rotting) • Clarify forms of energy that are released from energy sources <p><u>Decision making stage</u></p> <ul style="list-style-type: none"> • Group discussion to think of what are reasons to say “yes” or “no” for the question of “Should Thai government gives research money to scientists to study alternative energy or explore the unknowns of energy resources?” <p><u>Socialization stage:</u></p> <ul style="list-style-type: none"> • Activity of provide information to pose issues in web forum • Web forum • Group discussion for data analysis • Presentation of data analysis
2. Energy resources and energy formations (one sessions)	3, 4, 6, 10, 11	It might be time to use renewable energy. What kind of renewable energy would be used in Thailand?	<p><u>Identification of social issues stage:</u></p> <ul style="list-style-type: none"> • Classroom discussion on the situation increased price of petrol. • Brain storming what we should do, if we do not want government to pay amount of money for this <p><u>Identification of potential solution stage:</u></p> <ul style="list-style-type: none"> • Group discussion of volition of use renewable energy. <p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Brain storming to give example of something spread out

Table 5.1 (Continued)

Sub-units	Objectives	Issues	Activities
2. Energy resources and energy formations (one sessions)			<p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Discuss what the problem of spreading out energy is. • Link problem of spreading out to the concept of the second law of thermodynamic, energy transformation and degradation. • Do Exercise 2.1 – the second law of thermodynamic, energy transformation and degradation. <p><u>Decision making stage</u></p> <ul style="list-style-type: none"> • Group discussion to make decision what kind of renewable energy should be used in Thailand. • Plan to present project of use renewable energy (Home work) <p><u>Socialization stage:</u> Showing project of use renewable energy in school hall during lunch time (30 minutes)</p>
3. Generation power (4 sessions)	5, 7, 9, 11, 12, 13	The Mae-moa coal power plant has greatly polluted the air. Is it a responsible decision to close down this plant and stop it production? Why?	<p><u>Identification of social issues stage:</u></p> <ul style="list-style-type: none"> • Classroom discussion on the situation of Mae-moh situation <p><u>Identification of potential solution stage:</u></p> <ul style="list-style-type: none"> • Discuss and find the solution for this issue by giving students to think of (1) how will the effects for energy consumer if the Mae moh power plant is closed? (2) If the Mae moh power plant still runs, what will happen to people and environment? • Consider “how does the coal help generator to work?” and “Can we use something else to run generator?” <p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Do experiment of electromagnetic induction with a simple dynamo • Do experiment of electromagnetic induction with a simple dynamo • Study the process of generation power in hydro and coal fire power plants • Num-pong power plant trip to attend engineer power plant conversation <p><u>Decision making stage</u></p> <ul style="list-style-type: none"> • Collect the background information to think of what and how will be the best volition of the Mae-moh situation (homework) <p><u>Socialization stage:</u></p> <ul style="list-style-type: none"> • Organize role-play public hearing for finding the solution of the Mae moh situation • share ideas to the engineers

Outcomes of the Initial STS Energy Intervention

The initial STS energy unit not only enhanced students' understanding of energy concept but also gave chances school A students to develop their thinking skills, decision making about energy related technological and societal issues and gaining affective outcomes. The aspects of reporting include an overview of the initial classroom intervention, learning outcomes of students' energy concepts, the development of students' decision making and thinking skills classification through the STS approach, affective outcomes of the STS energy unit, and some difficulties of the STS energy teaching and learning. Then, the section discussed the implications for further the STS energy teaching and learning. Each aspect is discussed below.

1. Learning Outcomes of Students' Energy Concepts

This part discusses students' understanding of energy concepts. Students' homework and examination were interpreted their understanding of energy concepts. Students' understanding of energy sources and forms, the law of energy conservation, energy transformation and degradation are discussed below.

1.1 Students' Understanding of Energy Sources and Forms

Students' understanding of energy sources and forms could be viewed in what students did in the exercise sheets of sub-unit one and scored the energy test at the end of the unit. These aspects are discussed below.

1.1.1 Students' Understanding of Energy Sources and Forms in the Sub-unit One

In sub-unit one, the problem of oil embargo affect to Thailand raised students to know several forms and sources of energy. They had a chance to discuss the possible alternative energy that gave them to classify forms and sources of energy.

Exercise 1.1 revealed that students confused between forms and sources of energy, and had difficult to identify forms of energy.

A number of students still confused between forms and sources of energy. Energy forms were perceived as sources of energy. They viewed different kinds of energy sources as forms of energy resulting from fuel. For example;

Fuel has forms of energy including:

Heat energy, electric energy, and the sun (Sutree)

Heat energy, petroleum, alcohol, coal, natural gas (Franky)

Petroleum, natural gas, coal, propane, nuclear (Plao)

Although the exploration phase reported that electric energy was the most well known energy form by students, the exercise 1.1 revealed that some students confused electric energy as sources of energy. For example:

Name at least 3 resources of heat energy: geothermal, the sun, and electric energy (Jira), natural gas, the sun, and electricity (Plao)

A number of students had difficulty to identify forms of chemical potential and gravitational potential energy. They only gave their own name of energy forms such as tidal power, hydro power, digestion energy, and muscle energy. Additionally, majority of students did not recognize term of potential energy. For example:

Name forms of energy occurs in Battery: electric energy (Jum), electric and mechanical energy (Franky)

Name forms of energy occurs resulting from the water behind dam: electric energy and hydro power (Pao), electric energy (Jum), electric and mechanical energy (Suchati)

What form of energy is used during going up stair? Mechanical, digestion, and muscle energy (Sutree)

Someone identified the activities which use chemical potential energy e.g. walking and running. Example:

Name at least 3 resources of chemical potential energy: Battery, walking, running (Jum)

1.1.1 Students' Understanding of Energy Sources and Forms as Scoring in the Energy Test

Students' exercise 1.1 reminded the researcher to check on his teaching. The researcher found that the teaching paid too much attention on social issues. The researcher realized that the STS energy intervention should keep balance between students' energy concept and finding solution of social issues. The researcher corrected students' exercise and revise clarifying forms and sources of energy. This supported students' understanding of energy sources and forms that were evidenced as scoring in the energy test.

Students could classify energy sources. Table B6 revealed that the majority of school A students (36.2%) classified non-renewable and renewable energy source. The majority of school A students could identify forms of energy resulting from sources of energy. Table B3.1 revealed that the majority of school A students (48.9%) could correctly give main of forms resulting from a battery. Table B3.2 revealed that the majority of school A students (85.1%) knew that nuclear energy resulting when protons and neutrons were arranged into atomic nuclei. Table B3.3 revealed that the majority of school A students (59.6%) could identify kinetic energy. However, it seems that school A students still be difficult to identify chemical potential and gravitational potential energy. Table B3.4 and B3.5 showed that there were only 23.4% and 25.5% of school A students to be able to identify chemical and gravitational potential energy, respectively.

1.2 Students' Understanding of Energy Transformation

The development of students' understanding of energy transformation could be viewed in doing worksheet and exercise sheet in sub-unit two and three, students' examination. In sub-unit two, students' discussion of alternative energy and problem of energy spreading generated students to develop their understanding of energy transformation in energy sources and electrical devices. In sub-unit three, study how the different kinds of the power plant work gave students the concept of energy transformation in generating power. These aspects are detailed below.

1.2.1 Students' Understanding of Energy Transformation as Showed in Sub-unit Two

Exercise sheet 2.1 in sub-unit two revealed students' explanation of energy transformation in electrical devices and energy sources. First, students explained energy transformation in a television, a fan, and a lamp. Students' ideas were categorized into three description frameworks including event, one-step, and multi-step of energy transformation. The statistical details are showed in the Table 5.2.

In the description framework of event, students described energy transformation as the process of turning on electrical devices. Example:

Television: insert a plug into a socket → turn on a television → electric energy flow in → reaction energy → picture

Fan: insert a plug into a socket → turn on switch → electric energy flow in → chemical potential energy → rotation of a fan

Lamp: insert a plug into a socket → turn on switch → electric energy flow in → generate reaction → a lamp glowing (Chalerm)

In the description framework of one-step of energy transformation, students described changing of energy from one form into another form. They only

recognized obvious forms of energy or phenomena without other forms of energy spreading out. Example:

Television: electric energy → seeing

Fan: mechanical energy → wind

Lamp: electric energy → light energy (Pim)

In description framework of multi-step of energy transformation, students gave ideas of changing energy forms step by step into various forms of energy. Many students described heat energy as a non-useful forms of energy in their description. For example:

Television: Electric energy → light, sound energy and heat energy

Fan: Electric energy → Kinetic energy of rotation and heat energy of motor

Lamp: Electric energy → light energy and heat of lamp (Phaew)

Television: Electric energy → heat, light, and sound energy

Fan: Electric energy → mechanical energy and heat energy

Lamp: Electric energy → heat energy → light energy (Pron)

There were also many students who gave description of multi-step of energy transformation that sometime recognize heat energy in their descriptions. For example:

Television: electric energy changed into color, light, sound, and picture

Fan: Electric energy changed into mechanical energy

Lamp: Electric energy changed into light and heat energy (Jira)

Television: electric energy changed into light, sound, and heat energy

Fan: electric energy flowing into motor of a fan produces mechanical energy of a fan

Lamp: electric energy changed into light energy (Chan)

Table 5.2 Students' Description Framework of Energy Transformation in Electrical Devices

Framework	Television		Fan		Lamp	
	f	%	f	%	f	%
Event	4	9.3	2	4.6	2	4.6
One-step	12	27.9	18	41.9	25	58.2
Multi-step	27	62.8	23	53.5	16	37.2
Total	43	100.0	43	100.0	43	100.0

According to the Table 5.2, the statistics showed that the majority of students held framework of multi-step to describe energy transformation resulting from using a television and a fan. Additionally, a number of students used framework of multi-step. This indicated that students' discussion of alternative energy and problem of energy spreading supported them to consider other forms of energy which were not obviously observable. They did not only recognize ideal concept of energy transformation but also converting to several forms of energy.

Other items of exercise sheet 2.1 gave students to trace back energy forms resulting from using a car and an iron. Students' ideas of tracing back could be categorized into three categories including (1) far to unit of distribution, (2) far to the energy sources, and (3) far to the sun. The statistical detailed are showed in the Table 5.3.

Table 5.3 Students' Ideas about Tracing Back Energy Forms Resulting From Use a Car and an Iron

Categories	Car		Iron	
	f	%	f	%
Far to the unit of distribution	5	11.6	27	62.8
Far to the energy sources	25	58.2	13	30.2
Far to the sun	13	30.2	3	7.0
Total	43	100.0	43	100.0

(1) Far to unit of distribution. Students could trace back starting from kinetic energy and heat energy to unit of energy distribution such as a refinery plant, an oil well, gas station, and a power plant. For example:

Car's kinetic energy → Piston's kinetic energy → heat energy of oil → oil from gas station → oil from a refinery plant → an oil well (Chit)

Car's kinetic energy → Piston's kinetic energy → Heat energy of sparking engine → heat of burning oil → chemical potential energy → oil from gas station (Suri)

Heat energy of an iron → heating plate → electric energy from plug → electric energy from grid system → electric energy from a power plant (Korn)

(2) Far to the energy sources. Students could trace back starting from kinetic and heat energy to chemical potential energy of petroleum and deposit of living things, and gravitational potential energy of water reservoirs. For example:

Car's kinetic energy → Piston's kinetic energy → burning energy → heat energy → chemical potential energy of fuel → potential energy of petroleum (Franky)

Heat energy of an iron → heating plate → electric energy → kinetic energy of vapor → heat energy of water → heat energy of fuel → potential energy of oil → potential energy of deposited living thing (May)

Heat energy of an iron → heating plate → electric energy → mechanical energy → hydro power (Thana)

(3) Far to the sun. Students' tracing back energy form started from kinetic and heat energy to the sun and the Big Bang. For example:

Car's kinetic energy → Piston's kinetic energy → Heat energy of spark engine → chemical potential energy of petrol → potential energy of deposited living things → light energy → the sun (Pron)

Car's kinetic energy → Piston's kinetic energy → Heat energy of spark engine → chemical potential energy of petrol → Chemical potential energy of deposited living things → light energy → energy from the sun → Big Bang (Tee)

Heat energy of an iron → heating plate → electric energy → kinetic energy of vapor → heat energy of fuel → potential energy of deposited living thing → light energy → the sun (Bud)

According to the Table 5.3, there were quite a number of students who could trace back far to origin of energy sources and far to the sun. These two categories of students' ideas suggested that they concerned with concept of energy about "energy cannot be created but it can be transformed from other forms of energy". It evidenced that tracking back supported the development of students' understanding of energy transformation.

1.2.2 Students' Understanding of Energy Transformation as Showed in Sub-unit Three

Sub-unit three, the Mae moh power plant, allowed students to trace how the power plant worked and discussed energy transformation of the power plants. In work sheet 3.1, students had to describe energy transformation in a coal power plant. All the students gave description framework of the multi-step of energy transformation but there were different energy forms to be identified. Students' descriptions could be classified into three categories as follow.

Category A: fuel → heat energy → electric energy

Category B: coal → heat energy → kinetic energy of vapor → mechanical energy → electric energy

Category C: chemical potential energy → heat energy → kinetic energy of vapor → mechanical energy → electric energy

The statistical details of each category are showed in the Table 5.4. According to Table 5.4, the majority of students held description in the category B. This showed that they understood concept of energy transformation in coal power plant but they had trouble with the form of chemical potential energy. Only a few students could identify chemical potential energy in the description of energy transformation as appearing in the category C.

Table 5.4 Students' Description of Energy Transformation in a Coal Power Plant

Categories	Students' responses	
	f	%
A	14	43.7
B	16	50.0
C	2	6.3
Total	32	100.0

In the exercise sheet 3.2, students had to describe energy transformation in a hydro power plant. All the students gave description of energy transformation in framework of the multi-step but there were different identification of energy forms. Students' descriptions could be classified into three categories as follow.

Category A: water energy → pressure → mechanical energy of turbine → electric energy

Category B: potential energy → kinetic energy → mechanical energy → electric energy

Category C: Gravitational potential energy → kinetic energy of water → mechanical energy of turbine → electric energy and heat energy of coil

Table 5.5 Students' Description of Energy Transformation in a Hydro Power Plant

Categories	Students' responses	
	f	%
A	25	69.4
B	3	8.4
C	8	22.2
Total	36	100.0

The statistical detailed of each category is showed in the Table 5.5. All the categories showed students' description as step by step. Students had quite a good understanding of the concept of energy transformation but they could not correctly identify forms of energy. According to the Table 5.5, the majority of students held description in the category A. Again, this indicates that they had trouble with the form of potential energy.

1.2.3 Students' Understanding of Energy Transformation as Scoring in the Energy Test

Analysis of the energy test showed that a number of students could score the questions that related to energy transformation. The Table B3.14 in the Appendices showed that the majority of school A students (63.8%) could give correctly description of energy transformation resulting from a television. Table B18 revealed that a number of school A students (34.0%) understood that the amount of light energy produced from a lamp less than the amount of electrical energy used. Table B3.23 revealed that a number of school A students (29.8%) could select the best explanation of energy transformation resulting from the hydro generating power. Table B3.24 revealed that a number of school A students (31.9%) could select the best explanation of energy transformation resulting from the coal generating power. This indicated that there was the development of students' understanding of energy transformation in the initial classroom intervention.

1.3 Students' Understanding of Energy Degradation

As the simple concept of entropy, the concept of energy degradation involves energy spreading out and hard to become more useful energy. Students' understanding of energy degradation could be viewed in what students did in exercise sheet of sub-unit two, three and scored the energy test. These aspects are discussed below.

1.3.1 Students' Understanding of Energy Degradation as Showed in the Unit

Sub-unit two, students' ideas about energy degradation could be assessed when they did the exercise sheet. Students' energy description of energy transformation in electrical devices, showed in Table 5.1, found that the 14 students (32.6%) concerned with heat energy or waste heat as spreading out. For example:

Television: Electric energy → light, sound energy, and heat energy on behind TV)

Fan: Electric energy → Kinetic energy of rotation and heat energy of motor

Lamp: Electric energy → light energy and heat of lamp (Phaew)

Television: Electric energy → light and sound energy with the waste heat

Fan: Electric energy → mechanical energy. And, when it makes mechanical energy it also lost energy as heat energy.

Lamp: Electric energy → light energy and waste heat (Bud)

Sub-unit three, students' ideas about energy degradation could be viewed when they gave description of energy transformation in a power plant. Table 4.17 showed that a number of students (22.2%) gave description in category C which identified heat energy of coil. This indicates that they recognized heat energy spreading out when they gave description of energy transformation in the process of hydro generating power. However, it seems that they ignore energy spreading out when they have to give description of a longer step of energy transformation. In Exercise 3.1, students gave a description of energy transformation in a coal power plant. All the students gave description framework of multi-step of energy transformation but their descriptions never identified heat or other energy as energy spreading out. This suggests that they may be careless to give a description when they have to describe a long step of energy transformation.

1.3.2 Students' Understanding of Energy Degradation as Showed in the Energy Test

Analysis of the energy test showed that a number of students could score the questions that related to energy degradation. Table B3.12 of the Appendices showed that the majority of school A students (42.6%) gave ideas that stated "energy can be transformed into non-useful forms of energy (e.g. waste heat). This indicated that they applied concept of energy degradation to explain that people needed to save energy although the scientific knowledge stated that "the total of energy always stays the same".

Table B3.14 showed that the majority of school A students (63.8%) recognized heat energy spreading out when they selected a choice that represented energy transformation in a television. Table B3.23 showed that a number of school A students (29.8%) selected the description of energy transformation resulting from a hydro generating power which contained the heat spreading out. Table B3.24 showed that a number of school A students (31.9%) selected the description of energy transformation resulting from a coal generating power which contained the heat spreading out. Table B3.29 showed that the majority of school A students (59.6%) concerned with waste heat spread out during generation power process. These suggested that the majority of students recognized heat energy spreading out during energy transformation.

Table B3.18 showed that the majority of school A students (34%) thought that, to power a lamp, the amount of light energy produced less than the amount of electrical energy. This suggests that they recognized other forms of energy spreading out during powering a lamp. However, although a number of students perceived concept of energy degradation, there were not many students to recognize the second law of thermodynamics. Table B3.15 revealed that approximately twenty five percent of students could define this term.

1.4 Students' Understanding of the Law of Energy Conservation

It seems that students could perceive concept of the law of energy conservation. Previous topic discussed that the majority of students recognized the other forms of energy spreading out. These could assume that they perceived that the total amount of energy stays the same, energy could not be created or destroyed but it could be transformed from one form to other forms. Table 5.2 revealed that a number of students could trace back far to the sun and the Big Bang. This indicated that this activity supported them to recognize that energy could not be created or destroyed but it could be transformed form one to other forms.

Energy test showed that students had the development of students' understanding of the law of energy conservation. Table B3.16 revealed that a number of school A students (21.3%) correctly selected the two situations that represent the concept of the law of energy conservation. However, Table B3.17 showed that the majority of school A students (53.2%) understood statement of "Energy is transformed from one form to another form but the total amount of amount of energy stays the same" as concept of energy transformation. There were only approximately twenty percent of students who know that it was the law of energy conservation. This suggested that students could not clarify the relationship between the concept of energy transformation and the law of energy conservation. The law of energy conservation stated that the total energy an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same.

2. Development of Students' Decision Making about Energy Related Technological and Societal Issues.

The provided issues of the initial STS energy unit motivated the school A students to feel they needed scientific knowledge. The unit also enhanced students to generate their process of decision making. Students had to make a decision for a possible solution of those issues. As a process of decision making, themes of school A students normative decision model could be viewed including identifying possible way, developing criteria for decision making, validity and clarification of information, and choose an alternative. Their process of decision making for those issues were not only developed based on scientific knowledge but also their value judgments that were made based on the societal, economical, and environmental aspects. Details students' process of decision making and values clarification is discussed below.

2.1 Students' Decision Making and Value Clarification for Oil Embargo Issues

Sub-unit one raised the history of oil embargo side effect in Thailand. Students had to think of how to help Thailand that had no longer got side effect of oil embargo. Each group of students listed various possible ways of action in considering issue. These include using alternative energy (e.g. natural gas, palm oil, and solar power), making good relation to the OPEC group, campaign use of alternative energy, and giving fund for scientists to study alternative energy. Example:

Thailand should order directly the oil from OPEC. No more order the oil via the USA. We should make friends with the OPEC countries. Government should give funding for study renewable energy. (Chalerm's group)

We should use renewable energy in our country (Chu's group)

Thailand might use alternative as the energy resulting from crop, and using biomass energy. Government should give funding scientists to produce car that do not use oil. Advertise people to widely use biomass. (Jira's group)

Students evaluated the advantages and disadvantage when they chose the possible ways of action. All groups thought that Thailand should use alternative energy for protecting against side effects of oil embargo but they focus on the different kinds of alternative energy such as solar power, NGV gas, and bio diesel. Their value clarification was focused on both scientific knowledge and societal aspects. They clarified scientific information of engine combustion, strategies to produce bio diesel, and giving funding for study solar power. They thought that renewable energy sources as local materials would give cheap energy and safety for environment. They also concerned social aspects that could be viewed when they thought that using crop as renewable energy sources would help farmers to gain more profit because, actually, most of Thai farmers were very poor. For example:

Use solar power. We will not dependent on the OPEC anymore but government needs to give funding for studying solar power in a car. If we can produce it, it will not be expensive. (Chalerm's group)

We should use the oil resulting from natural. We can produce oil from coconut and palm for use in a car. It will not be expensive because we have these materials in Thailand. Additionally, this kind of energy does not give environment damages. Therefore, we will have our own energy sources. (Chu's group)

However, some groups valued their decision only depending on environment effects, for example:

We should use NGV gas because it was produced in Thailand and decrease air pollution. (Chan's group)

These assume that many groups of students held multidimensional value clarification for decision making. Their decision depended on scientific knowledge, the economic aspects, environment effects, and societal aspects.

2.2 Students' Decision Making and Value Clarification for Issue of the Increased Petrol Price

In unit two, students discussed the situation of increased price of petrol. Although the government paid money to fix the petrol price, it was continually increased. The situation fosters students to find a solution in the long run. Students' ideas were quite similar with sub-unit one. All the students thought that the possible way is use the renewable energy. They clarified the information known about possible alternatives that involving analysis resources and studying the example of use renewable energy. For example:

It is possible to use the rubbish for generating power in Thailand. Scientists might use scientific knowledge to analyze how it is possible. (Tas's group)

There is example of use renewable energy. We heard that the King Bhumibol project did the bio diesel. They fermented the crop to produce bio diesel.
(Phoa's group)

Then students listed possible kinds of renewable energy sources including solar power, gasohol, rubbish, and bio diesel. They clarified the advantages and disadvantages of each alternative. Their value clarifications include use local materials, scientific knowledge, environmental concerns, the price, economical aspects, solving social problem, and safety. For example:

The disadvantages of use solar power include: 1) too expensive, 2) to be difficult to find materials of solar cell because we need to import, 3) use only during light time, and 4) we need knowledge to use this kind of energy. The advantages of use solar power include: 1) given a lower level pollution, 2) no cost of light energy, 3) no effects to the natural, 4) safety use, and 5) it is convenience to use. (Jira's group)

The advantages of use gasohol include: 1) solve the problem of a low price of crop, 2) given a lower level of air pollution because gasohol contains with the oxygen, 3) cheaper price. The disadvantage of use gasohol is no convenience because there is only one ethanol plant in Thailand and a few gasohol stations.
(Phaew's group)

The advantages of use rubbish for generating power include: 1) no cost of rubbish, 2) relieve the economic ruin. The disadvantages of use rubbish include: 1) take time to studying technology, and 2) lose a huge amount of budget to study. (Phol's group)

Finally, students choose the possible project to consider this issue. Six groups of students organized the campaign for energy saving in their school. Four groups of students organized the project for cultivating the use of renewable energy sources. Above discussion could assume that a process of students' decision making aware of the relationship between science (energy), technology, and society.

2.3 Students' Decision Making and Value Clarification for the Mae moh Situation

Unit three raised the issue of air pollution surrounding the Mae moh coal power plant. Students organized role-play to find the solution for the Mae moh situation after studying in the need knowledge stage of teaching. Students organized a talk show role-play that named “Thung Oak Thung Jai” (the Extremely Hit the Point Talk Show). Students were separated into four groups including the power plant officers, environment organization, government, and people who live in the Mae moh district. Each group received background information in each favor. However, each group of students had to find more information to develop criteria to decide whether the Mae moh power plant should be closed or not.

The “Thung Oak Thung Jai” allowed student’s representative in group of environment organization (Tuy), government (Nad), the power plant officers (Ja), and people of the Mae moh district (Phol) to testify. Most of them want to close down the Mae moh coal power plant. Initially, they identified the criteria for decision making. It seems that their important criteria are environmental effects and the safety of the Mae moh people. For example:

M.C: Well, we will start with the government representative. Sir, what is your opinion about the Mae moh situation.

Nad: I think that we might construct new kind of the power plant in Mae moh.

M.C: What are the main points that support your ideas?

Nad: Coal. Yes, coal.

M.C.: Why?

Nad: It gave air pollution.

M.C: Sir, can you give us more information?

Nad: The coal power plant generates environment damages. I mean that the crop and people cannot survive there.

Then, students moved to clarify possible alternative solutions. Most of them proposed that the Mae moh should have a new kind of power plant that did not release air pollution. They listed several types of power plants including a hydro, a solar and a wind power plant. They considered what kinds of energy sources could be used instead of coal. The hydro, solar and wind power were considered because they are safe for environment and people. Additionally, a high cost of constructing a solar power plant also was criticized. For example:

M.C: We have already heard their opinion. Most of them thought that the Mae moh power plant should be closed down. So, we come back to the government representative. What energy sources can we use here?

Nad: we can use the hydro power of a dam.

M.C: Could you please give us more information?

Nad: I think that we might close the coal power plant. Then, we might construct a new hydro power plant.

M.C: Tuy, if the Mae moh coal power plant is closed down, what kind of energy will be substituted here?

Tuy: I think hydro power will be OK.

Phol: I live at Mae moh for long time. Now, the Mae moh have changed. Here, there is an amount of dust that makes us unhappy to live here. We don't want it at all. I think we can construct solar power and the wind power plant here.

M.C: Is it worthwhile?

Phol: Yes, it is.

Students' representative in group of the power plant officers thought that the Mae moh coal power plant should not be closed down. They thought that scientific knowledge could solve the problem of air pollution. The problems of unemployed person were also discussed. For example:

Ja: I think that we will no longer generate the air pollution because we have the machine to eliminate the sulfur dioxide. I think we can decrease sulfur dioxide that polluted the air now.

M.C: Is it worthwhile to pay for that machine?

Ja: Yes, it is because we do for the people. And, it is people money that government pays for us.....

Ja: If the power plant is closed down, where will the power plant officers work? How are their children lives?

Finally, students voted to choose the possible solution by writing their ideas in a piece of paper. Interestingly, there were two mode of students' opinion both agreement and disagreement to close down the Mae moh power plant. The 16 students, who agreed to close it down, clarified their ideas mostly involving environment effects. For example:

It should be closed down because it released bad thing that damaged environment.

Close it because it causes people to get sick.

It should be closed down because although no more the coal Mae moh power plant, there are several kinds of power plant.

The 14 students, who disagreed to close down it, mostly concerned with electric energy supply, budgets, and economic effects. For example:

It should not be closed down because it affected use electric energy in other part of Thailand.

It should not be closed down because constructing the new power plat had to spend amount of money and take time.

It should not be closed down because it is a big power plant. Without it might cause to ruin Thailand's economic.

Above discussions assumed that their value clarifications were based on scientific knowledge, economical, societal, and environmental aspects.

3. Development of Students' Thinking Skills

Consideration in students' discussion and writing in worksheets could reflect their thinking skills. Students' thinking skills were extracted when they expressed their complexity of questions and statements that involved application, analysis, value judgment, and expression of an opinion regarding controversial issues.

The issues supported students to clarify information known about alternative energy that required application. For example, students clarified information known during listing the possible renewable energy sources to deal with issues as follow:

Can biogas be used for cooking? And, how can we produce biogas? Does it have a bad smell? (Jira's group)

Although the petrol price is continually increased, majority of cars use benzyl and diesel. A few use alcohol because people cannot modify their car to be able drive with alcohol. (Chu's group)

The issues of oil embargo and the increased price of petrol allowed students to clarify value judgment and expression of an opinion regarding controversial issues.

For example:

Thailand should order directly oil from OPEC. No more order the oil via the USA. We should make friends with the OPEC countries. Government should give funding for study renewable energy. (Chalerm's group)

It is possible to use the rubbish for generating power in Thailand. Scientists might use scientific knowledge to analyze how it is possible. (Tas's group)

Students' thinking in worksheet showed that they knew how to apply value judgment. This could be viewed all the time when students reasoned for possible

alternative renewable energy use in Thailand, and discussion in the role-play of the Mae moh situation. For example:

The advantages of use solar power include: 1) given a lower level pollution, 2) no cost of light energy, 3) no effects to the natural, 4) safety use, and 5) it is convenience to use. (Jira's group)

Ja: If the power plant is closed down, where will the power plant officers work? How are their children lives? (The student representative of the power plant officers group)

Validation for possible alternative renewable use also allowed students to develop their analysis thinking. For example, they analyzed the factor to influence the price of renewable energy as follow:

We can produce oil from coconut and palm for use in a car. It will not expensive because we have these materials in Thailand. (Chu's group)

Role-play of the Mae moh situation allowed students to develop their analysis thinking. They analyzed the effect of closing down the Mae moh power plant such as shortage of electric energy in wide area, forest ruining because of constructing a new hydro power plant, and the worth of constructing a new solar power and wind power plant. For example:

Nad: I think that we should close down the coal power.

M.C: The Mae moh distribute electric energy in a wide area, doesn't it?

Eighty percent of the Northern part of Thailand use electric energy from here. So, how can we handle this?

Tuy: Like Nad said. I think that water power should be used instead of coal.

M.C: I wonder. If the dry season comes, is there water enough for generating power?

Tuy: We can construct more dam, and then we have enough water.

M.C: You are ecologist, aren't you? You might know that constructing a dam also destroys the forest.

Phol: I live at Mae moh for long time. Now, the Mae moh have changed. Here, there is amount of dust that gives us unhappy to live here. We don't want it at all. I think we can construct solar power and the wind power plant here.

M.C: Is it worthwhile?

Phol: Yes, it is.

Role-play of the Mae moh situation also gave a chance all the students to develop their thinking with expression of an opinion regarding controversial issues. Their opinion showed the different value clarification. For example:

The Mae moh power plant should be closed because it causes the ecology system damages, air pollution, people got sick.

The Mae moh power plant should not be closed down because it affected use electric energy in other part of Thailand.

These assumed that the initial STS energy unit enhanced students' thinking. Their discussion and writing suggested that they applied value judgments to available information, and to understand that some problems may have more than one possible solution or may not even have a solution at all. They knew how to clarify information to solve complex problems that involve energy, technology, and society in effective way.

4. Gaining Affective Outcomes

In the first week of the initial STS energy unit, it seemed that students had difficulty for discussion activities. The researcher observed that there were a few group able to discuss to each other. The rest of them only followed the ideas of head of the group gave. Students' interviews revealed that they needed teachers to tell the truth rather than inquire by themselves. They were unfamiliar with this learning style.

They thought that they needed to adapt their learning style as follows in the example of students' comment:

R: Do you think that this unit gives you too much discussion?

Phaew: I am OK. Actually, I am learning in a former curriculum. I am adapting my studying. Normally, I was taught by lecture and doing some report. I never searching, reporting, and do everything without teachers' telling. If we totally do everything and studying by ourselves, how can we know what is right or wrong?

In the following weeks, the initial STS energy unit could motivate students to learn energy. Students' interviews revealed that there were interesting activities of the unit. An overview of students' reasons involved enhancing their analysis thinking, learning about unexpected knowledge, and feeling fun to some discussion issues. Each aspect is discussed following.

Some students liked to learn this energy unit because they have chance to develop their analysis thinking. Bud commented:

Researcher: Could you comment this unit?

Bud: ... It is useful because it allows me to develop my analysis thinking. I think we should exercise our brain rather than only wait for teachers' telling and then remember what they say.

Researcher: So, what has developed your analysis thinking?

Bud: Lots of things. For example, we talked about if we should burn the rubbish for producing energy. And, what types of renewable energy sources should be used in Khon Kaen?

Additionally, the unit allowed students to find further information about energy. Some students appreciated their learning about energy in unexpected knowledge. For example:

Jira: I knew the strategies to produce biogas from posing issue on webboard of Vicharkarn.com. I knew that a carcass and died plants could also produce biogas.

Researcher: Have you found this in any books?

Jira: I have read in a reading sheet but they described others that never seen in worksheet.

Researcher: Do you like it?

Jira: Yes, I do because I never expect that I will know this.

It seemed that this unit provided too much discussion. Some students had trouble with discussion for possible alternative solutions of the issues. However, they found that sometimes discussion gave them fun (e.g. role-play of the Mae moh situation) for energy learning. As Khauw commented:

Researcher: So, do you want teachers to give you more lectures?

Khauw: Yes but sometimes. I think I want exchangeable styles. I mean both students' discussion and teachers' lecture.

Researcher: Why?

Khauw: Sometimes, lecture is boring. I can read in reading sheet. Sometime, discussion was fun, for example, talking about the Mae moh situation.

Observation of students' role-play of the Mae moh situation seemed to confirm that how they had fun in discussion. All the students expressed their emotion along their favor. They dressed up as a farmer at the Mae moh, a politician, an engineer, and ecologist. They tried to make jokes during discussing such as coughing because of air pollution, using a powder to make dust, and make a voice like a politician.

Above discussion assumed that the initial STS energy unit fostered students' affective of energy learning.

5. Implications for Further Energy Teaching and Learning Through the STS Approach

Analysis and interpretation of the initial STS energy unit suggested aspects of energy teaching and learning. The following aspects gave implications for improving the STS energy unit and providing participating teachers of the further trialing during enhancing the STS energy teaching.

(1) Students take time to cope with each social issue but there are a number science content standards to be achieved for Thai Grade 9 students. To manage science teaching, teachers may integrate more several concepts into the initial STS energy unit.

(2) The issue of oil embargo and the increased price of petrol raised students' ideas of possible alternative and related energy concepts. The issue of oil embargo seemed to be far from students' interests. Therefore, the further trialing of the STS energy unit could be reduced into two sub-units including the issue of the increased price of petrol and the Mae moh situation.

(3) Students should be motivated for learning as passive learners. It seemed that students had difficulty for discussions. They were unfamiliar with this learning style of the initial STS energy unit. They needed teachers' lecture rather than inquiry by themselves.

(4) The issues gave students chances to clarify their values for decision making. Their values concerned with various aspects including scientific knowledge, economic aspects, environment concerns, and societal aspects. However, teachers need to foster students to evaluate the advantages and disadvantages of the possible solutions or ways of actions for the local students' communities.

(5) Teachers should give more chance to all the students to express their thinking. Students' thinking showed some unexpected opinions and values

clarifications. All participation may suggest the multidimensional aspects to reach possible alternative.

(6) The STS energy intervention should keep balance between students' energy concepts and social issues. It seemed that teaching paid too much attention on social issues during the first week of the initial STS energy intervention. This might affect the development of students' understanding of energy concepts.

(7) Students should be enhanced more to clarify forms and sources of energy. The initial STS energy unit intervention reflected that students seemed to still be confused between forms and sources of energy. Particularly, identifying forms of potential energy, a number of students had difficulty to identify forms of chemical potential and gravitational potential energy. They usually gave tidal power, hydro power, digestion energy, and muscle energy to identify the potential energy. Students' mistakes of identifying energy forms affect their description of energy transformation. Although they understood the concept of energy transformation, they could not clearly describe it because they could not recognize energy forms.

(8) Students should not only be supported to understand the ideal concept of energy transformation but also converting to several forms of energy. Students' discussion of alternative energy and problem of energy spreading supported them to consider other forms of energy which were not obviously observable.

(9) The participating should enhance students' existing ideas about energy degradation. Concept of energy degradation supported students' understanding of energy transformation. The majority of students recognized heat energy spreading during energy transformation. They could recognize the heat energy spreading when they gave a description of energy transformation in electrical devices and the process of generating power.

(10) Students should be reminded to clarify the relationship of energy transformation and degradation, and the law of energy transformation. It found that a

number of students understood statement of “Energy is transformed from one form to another form but the total amount of energy stays the same” as concept of energy transformation. This suggested that students could not clarify the relationship between concept of energy transformation and the law of energy conservation.

Summary of Chapter 5

The intervention phase involves developing the initial STS energy unit and then trialing this unit by the researcher in school A. The chapter detailed the designing the initial STS energy unit. Then, the chapter discussed the outcomes of the initial STS energy intervention to give implications for enhancing the STS energy teaching in the evaluation phase. Each aspect is highlighted below.

Developing the STS energy unit aimed to allow students’ energy learning through identifying problems with local interest and impact about energy related technological and societal issues, and then solving that issues. The unit, therefore, was developed based on the assumptions regarding students’ existing ideas about energy, and energy related technological and societal issues. In order to enter the relationship between science, technology, and society into the energy class, the STS energy unit was developed through five stages. These included an identification of social issues, identification of potential solutions, need for knowledge, decision-making, and socialization stage. The initial STS energy unit consists of three sub-units. The classroom activities were summarized in the Table 5.1.

Then, the initial STS energy unit was trialed by the researcher in the school A. This initial trialing aimed to find some suggestions for enhancing the STS energy teaching in three different schools. The outcomes revealed that the initial STS energy unit not only enhanced students’ understanding of energy concept but also gave chances the school A students to develop their thinking skills classification, and decision making about energy related technological and societal issues and gaining effectiveness to the energy unit. Each aspect is summarized as below.

The development of students' understanding of energy concepts includes energy forms, energy transformation and degradation, and the law of energy conservation. The energy test revealed that approximately fifty percent of students could identify forms of energy resulting from the energy sources although a number of students were confused between forms and sources of energy during doing worksheet. The students' worksheet indicated that the majority of students held framework of multi-step to describe energy transformation resulting from using electric devices and the process of generating power. Students' ideas about tracing back energy forms resulting from using a car and an iron revealed that there were quite a number of students who could trace back far to origin of energy sources and far to the sun. These suggested that they did not only recognize ideal concept of energy transformation but also converting to several forms of energy. Students' framework of multi-step also indicated that they consider energy degradation. Students' worksheet revealed that approximately thirty percents of students concerned with the heat energy or waste heat as spreading out for describing energy transformation in electric devices and the process of generating power. Additionally, it seemed that students' gaining understanding of energy transformation and degradation supported their understanding of the law of energy conservation. The energy test showed that approximately fifty percent of students corrected its definition.

The initial STS energy unit also enhanced students to generate their process of decision making. As a process of decision making, themes of school A students normative decision model could be viewed including identifying possible way, developing criteria for decision making, validity and clarification of information, and choose an alternative. Their process of decision making for those issues were not only developed based on scientific knowledge but also on their value judgments that were made based on societal, economical, and environmental aspects. For example, students thought that Thailand should use alternative energy for protecting the side effect of oil embargo because they concerned with cheaper budget of the local materials and helping farmer to gain more profit. Students began solving the situation of the Mae moh power plant that polluted the air by listing the other types of power

plant. Hydro, solar and wind power were considered because they safe for environment and people living. However, they were aware of a high cost of constructing a solar power plant as well.

The initial unit enhances students to develop their thinking skills classifications. This could be seen when they expressed their complexity of questions and statements that involved application, analysis, value judgment, and expression of an opinion regarding controversial issues. These questions and statements, for example, include:

Can biogas be used for cooking? And, how can we produce biogas? Does it have a bad smell?

We can produce oil from coconut and palm for use in a car.

Is it possible to use rubbish for generating power in Thailand?

The Mae moh power plant should not be closed down because the government would lose the budget. We just eliminate the bad smoke.

Students' reaction to the unit revealed that they had affective to the unit. Students were interesting activities of the unit because it fosters their analysis thinking, learning about unexpected knowledge, and fun of some discussion issues.

According to the outcomes of initial trialing, it illustrated the strength of the energy teaching and learning through STS approach. Students not only gained their understanding of energy concept but also developed their thinking skills classification, and decision making. These results had some implications for enhancing the STS energy teaching and learning. These include the following aspects. The STS energy teaching and learning should be reminded that students would take time to cope with each social issue. To manage science teaching, teachers may integrate more concepts into the initial STS energy unit. Paying too much attention on social issues might affect the development of students' understanding of energy concepts. The STS energy intervention, therefore, should keep balance between students' energy concepts and social issues. In order to foster students to

concern with various aspects, teachers would guide them to evaluate the advantages and disadvantages of possible solutions or ways of actions. It has been found that students' thinking showed some unexpected opinion and value clarifications. Teachers should give more chance all the students to express their thinking in order to reach suggest the multidimensional aspects of possible way of actions. In order to enhance students to understand energy concepts, students should be reminded to clarify the relationship of energy transformation and degradation, and the law of energy transformation. The finding about students' understanding of energy concepts assumed that this relationship supported their understanding of the law of energy conservation. Identifying energy forms should be emphasized. The initial trialing revealed that students' mistakes of identifying energy forms affect their description of energy transformation. Teachers should be reminded that energy degradation should not be ignored because energy spreading supported students to consider other forms of energy, which were not obviously observable in energy transformation. It also supported students to well understand the law of energy conservation.

CHAPTER VI

EVALUATION PHASE

This chapter presents enhancing the STS energy teaching and learning that could be viewed as the further trialing of the STS energy unit. The further trialing was carried out in three schools of Khon Kaen province, Thailand, including school B (located in the city), school C (located in small town), and school D (located in rural area). The program of enhancing STS energy teaching and learning was developed based on participating teachers' existing ideas that have clarified previously in the chapter four. Therefore, the chapter begins with the details of the program of enhancing STS energy teaching and learning. Then, teachers and students' reflection to the STS energy unit are discussed. Each aspect is discussed in the following sections.

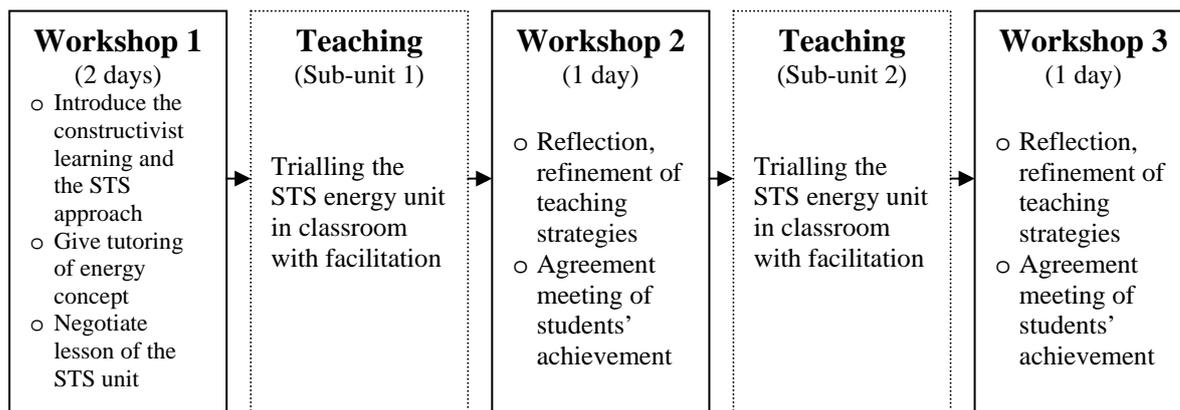
Program of Enhancing the STS Energy Teaching

Participating teachers who have to attend the program of enhancing of the STS energy teaching include Kunya, Ann, and Pim. School B teacher Kunya graduated as Bachelor of Education in home economic. Her science teaching experiences is 16 years. School C teacher Ann graduated as Bachelor of Education in science for lower secondary school. Her science teaching experiences is 14 years. School D teacher Pim graduated as Bachelor of Education in biology. Her science teaching experiences is 10 years.

This program was provided based on the existing participating teachers' ideas about energy concept and energy teaching and learning. The Questionnaire for Teacher Energy Perception (QTEP) and interviews gave information of existing teacher ideas that were detailed in the chapter four. Teachers' existing ideas indicated that they should be trained to develop their understanding of energy concepts and application of energy. The program provided full-day workshops followed trialing in classrooms. Three workshops were carried out as shown in Figure 6.1. Workshops

were placed between classroom teachings in order to provide teachers with opportunities to build stronger foundations for enhancing their teaching. Each section of the program is clarified more as below.

Figure 6.1 Timeline for Program of Enhancing the STS Energy Teaching



1. The First Workshop

The first workshop was provided to enhance teachers' existing ideas of energy concepts and energy teaching through STS approach. Tutoring of energy concepts was given with the goal to develop qualitative teacher understanding of energy concepts. Because of concerning Thai culture about teacher (e.g. teacher is respected person; teacher should not be insulted about knowledge); tutoring of energy concept was conducted beginning with teachers' group discussion to consider and develop students' ideas of energy, and then it gave teachers scientific ideas of energy. Student energy ideas were discussed in section of the Result of Exploration Phase, Chapter four. From the findings of teachers' existing ideas in aspect of energy teaching and learning concerned with the constructivist theory of learning, the workshop also provided teachers the constructivist learning and the STS approach in order to connect to teachers' ideas of general pedagogy. Participating teachers negotiated lesson plan of the STS energy unit, designed by researchers, and to refine teaching strategies of the intervention unit during the second and third workshop. Negotiation may help them to gradually move from existing ideas and practices to a new negotiated position.

The STS energy lesson plan was provided for teachers' negotiation of the STS energy teaching and learning. The STS energy unit was rearranged from the initial STS energy unit. This STS energy unit comprises of two sub-units. The objectives of intervention are the same the initial STS energy unit that is mentioned previously in the chapter five. Classroom activities were outlined for sub-units which were arranged into a unit of work as shown in Table 6.1.

2. The Second and Third Workshops

The second and third workshops aimed to reflect and refine teaching strategies that concerned with the STS approach. Agreement meeting of students' achievement might suggest the alternative way of considering students' learning. These might build stronger foundations for enhancing their teaching

3. The STS Energy Teaching

While working in classrooms, the researchers suggested them to focus on students' critical thinking for solving social problem related energy and technology, and enhance students to consider dichotomize (e.g. advantage and disadvantage, use and abuse) for decision making. Researchers also reminded teachers to give questioning students' existing energy ideas and reflection students the scientific ideas of energy. Teacher agreement meeting allowed teachers to reach close consensus about developing of students' understanding energy concepts, critical decision making and thinking skills.

Table 6.1 Outline of the STS Energy Lesson Plan

Sub-units	Objectives	Issues	Activities
1. Use energy in Thailand (8 sessions)	1, 2, 3, 4, 6, 11, 12	How could we find the solution for the increased price of petrol?	<p><u>Identification of social issues stage:</u></p> <ul style="list-style-type: none"> • Classroom clarification of the situation of the increased price of petrol. • Brain storming to make the sceptical ideas about the increased price of petrol • Conclude and categorize trends of question orientation. <p><u>Identification of potential solution stage:</u></p> <ul style="list-style-type: none"> • Brain storming for possible solutions of each oriented question category • Clarify the related knowledge known and unknown <p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Study energy forms and sources such as definition of energy forms, name the energy sources and its form of energy • Classify forms and sources of energy. • Study various types of energy sources (renewable and non-renewable energy) • Group discussion of alternative energy. • Clarify the nature of energy • Do experiments of renewable energy sources including the solar power (radiant energy is transformed to heat energy), solar cell (radiant energy is transformed to electric energy). • Discussion the use of other renewable energy <p><u>Decision making stage</u></p> <ul style="list-style-type: none"> • Revise the situation of the increased price of petrol. • A group planning of the possible action projects for alternative solution. • Present group planning of a project. <p><u>Socialization stage:</u></p> <ul style="list-style-type: none"> • Run each group project (e.g. projects of energy saving, or use renewable energy) • Present the project reflection • Identify the possible improvement.
2. Generation power (8 sessions)	5, 7, 10, 13	How can we find the solutions for the demand in electric energy and the problems of the power plant that polluted the air?	<p><u>Identification of social issues stage:</u></p> <ul style="list-style-type: none"> • Classroom clarification of the situation of the Mae moh power plant that polluted the air. • Brain storming to make the sceptical ideas about the Mae moh power plant situation. • Conclude and categorize trends of question orientation. <p><u>Identification of potential solution stage:</u></p> <ul style="list-style-type: none"> • Brain storming for possible alternative solutions of each oriented question category • Clarify the related knowledge known and unknown

Table 6.1 (Continued)

Sub-units	Objectives	Issues	Activities
2. Generation power (8 sessions)	5, 7, 10, 13	How can we find the solutions for demand in electric energy and the problems of the power plant that polluted the air?	<p><u>Need for knowledge stage:</u></p> <ul style="list-style-type: none"> • Do experiment of electromagnetic induction with the simple dynamo • Do experiment of electromagnetic induction with the simple dynamo • Study the process of generation power in hydro and coal fire power plants. • Clarify energy transformation in the process of generating power. • Search more the other kinds of the power plants (e.g. the wind power, the nuclear, and the solar power plant). • Num-pong power plant trip to attend engineer power plant description of the Num-pong combined with heat cycle power plant. <p><u>Decision making stage</u></p> <ul style="list-style-type: none"> • Revise the situation of the increased price of petrol. • Plan and search more information for the role-play of the Mae moh situation. <p><u>Socialization stage:</u></p> <ul style="list-style-type: none"> • Organize role-play of the Mae Moh situation as public hearing. • Num-pong power plant trip to share engineer some alternative solution for the power plant that pollute the air.

Teachers and Students Reflection to the STS Energy Unit

Participating teachers and students' reflection would illustrate how the STS energy unit worked. Students' reflection includes the students' understanding energy concepts, students' thinking and decision making skills, and students' reaction to the unit. Teachers' reflection includes an understanding of the STS approach and energy concepts, and teachers' reaction to the unit. Below each school reflection will be discussed and then compared and contrasted in this reflection among school B, C, and D.

1. The School B Reflection

School B is located in the city, Khon Kaen. The total number of students of school B Grade 7 – 12 approximately includes 3,000 students. Kunya is the

participating teacher of the school B. She graduated as Bachelor of Education in home economic. Her science teaching experiences is 16 years. Kunya' school loading are not only science teaching but also the secretary of the school business affair.

Her participating Grade 9 science class includes 49 students, 37 girls and 12 boys, who live in the city of Khon Kaen and other small towns nearby the city of Khon Kaen. Their parents work for business sectors and government offices. The interesting source of energy learning in school B is the Green Classroom that was provided and financially supported by the Electricity Generating Authority of Thailand (EGAT).

The school B further trialing the STS energy unit is illustrated into various aspects. These include the school B students' reaction for energy learning and the unit, and teacher school B reflection to the unit. Each aspect is discussed below.

1.1 Overview of the School B STS Energy Unit Class

School B Teacher Kunya interpreted the lesson plan and provided her teaching after finishing the first workshop of the provided program for teaching the STS Energy. She conducted the STS Energy teaching during early November to late December, 2004. She spent 7 weeks, 18 hours of the STS energy teaching and learning.

The Identification of social issues of her sub-unit one, she allowed students to pose questions to the situation of Thai government paying for fixing the petrol price. Posed questions were classified for giving information. Learning activities were provided along with posed questions including discussing renewable energy sources; experiments of transforming the Sun's radiation energy to heat; experiments of solar cell generating electric energy; and discussing energy use in view of the law of energy conservation, energy transformation and degradation. Kunya enhanced

students to present their ideas in community. Students' projects included energy saving, and the use of renewable energy sources.

In sub-unit two, Kunya presented students the situation of the Mae-moh and allowed students to pose questions. Posed questions were classified into group. Learning activities were provided along with posed questions including discussion of grid of power system, experiments of inducing electric energy, trip to the Num-pong power plant, discussing the power plant, discussion of energy transformation and degradation of the Num-pong and the Mae moh power plant. Experiments about generating power were done in the Green Classroom that was provided and financially supported by the Electricity Generating Authority of Thailand (EGAT). The activity of the socialization stage was the role-play to solve the problem of the Mae moh situation.

1.2 School B Student Reflection

The STS Energy unit allowed students to learn the definition of energy, the law of energy conservation, energy transformation and degradation through social issues related to energy and technological aspects. School B students have not only developed their understanding of energy concepts but also critical decision makings and thinking skills. They held also positive attitude towards the STS Energy learning. These aspects will be discussed next.

1.2.1 School B Students' Understanding of Energy Concepts.

The development of students' understanding of energy concepts were considered comparing to their existing ideas before classroom intervention that has been discussed in the Section one of the Chapter Four. These include students' understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. Each aspect is discussed below.

A. School B Students' Understanding of Energy Sources and Forms.

Their existing ideas identified that they confused between forms of energy and sources of energy. The development of students' understanding of energy sources and forms could be clarified from their discussion in classroom and energy test score.

Teacher Kunya provided several energy sources for solving situation of petrol price and classifying forms of energy helped students to gain their understanding. Students could distinguish forms and sources of energy. They could clarify energy forms and sources. Forms of elastic, chemical, and gravitational potential, radiant, kinetic, and nuclear energy were given for the resulting from a several energy sources of energy. Their energy sources given include harvesting rice, pedal a bicycle, dancing, playing, nuclear bomb, grilling and roasting, bungee jumping, and stone on cliff. Examples of students' ideas follow:

The water in dam results the gravitational potential energy. Car, ball, and something moving result the kinetic energy. X-ray and radio wave has the radiant energy. (Nut)

The nuclear bomb and the uranium have nuclear energy. Coal, oil, and gas have chemical energy (Da)

The bungee jump results the elastic potential energy. The water in dam results the gravitational potential energy. Dry cell, food, and petrol give chemical potential energy. (Phan)

Grilling and roasting use the radiant energy. Spring and elastic band give the elastic potential energy. (Kaew)

Students' responses in the energy test revealed that the majority of students could identify forms and sources of energy. It assumed that students developed their understanding of energy forms and sources. These included correcting the main energy forms given from battery; recognizing the definition of kinetic and nuclear energy; and identifying sources of renewable energy and its forms.

Table B3.1 in Appendix revealed that the majority of school B students (81.6%) could correctly give main of forms resulting from a battery. Table B3.2 revealed that the majority of school B students (81.4%) knew that nuclear energy resulting when protons and neutrons were arranged into atomic nuclei. Table B3.3 revealed that the majority of school B students (77.6%) could identify kinetic energy. Table B3.6 revealed that the majority of school B students (65.3%) could classify non-renewable and renewable energy sources.

However, it seemed that students had difficulty to clarify forms of potential energy. The energy test showed that the majority of students were confused what sources of energy gave types of potential energy. Table B3.4 and B3.5 revealed that there were not a number of school B students able to identify gravitational and chemical potential energy. These might result from their missing key idea of potential energy. Potential or possibility of doing work was expected to be understood as key idea of potential energy but there were a few students (20.4%) to perceive this idea as shown in Table B3.11.

B. School B Students' Understanding of Energy Transformation

The exploration phase revealed that the majority of school B students' existing ideas concerned with description of energy transformation in generating power through a framework of multi-step. This indicated that they would be easier to develop understanding of energy transformation. However, their descriptions of energy transformation in using electrical devices were clarified through the framework of one step and the event.

To gain students' understanding of energy transformation, Teacher Kunya fostered students to clarify their description of energy transformation during the study of energy sources and generating power. For example, students clarified the energy transformation for the radiant energy of the sun during their experiment of solar cell as students' discussion below:

Da: Take the lamp closer to the solar cell. See! It makes the fan turning faster.

Ji: Let, try to exchange the anode and cathode.

Teacher Pim: Students, what did you find?

Ji: The light gives heat energy and then it is changed into the electric energy.

Da: Solar cell changes the radiant energy of the light to the electric energy.

Teacher Pim: What does the quantity of electric energy depend on? How does it affect the increasing or decreasing electric energy?

Muay: the angle of the light

Da: the distance of the sources of light

Energy transformation in generating power was also clarified. It seemed that students could apply their understanding of energy transformation. For example, students presented what they learned from the power plant trip. They clarified their knowledge about energy transformation in the Num-pong power plant. The technical terms (e.g. super steam) was also mentioned during their report as below.

Ju: The Num-pong power plant is the biggest power plant in the northeast. It can decrease the distribution of the power from the north and eastern power plant. It is the combined cycle power plant using both the natural gas and diesel.

Da: This power plant uses the gas turbine to turn on the generator.

Nut: Generator?

Da: Generator changes the mechanical energy into electric energy.

Ju: The super steam is used turning the gas turbine. The kinetic energy of steam is changed to the mechanical energy.

Nut: the super steam is very hot steam.

The energy test showed that a number of school B students could give the best explanation of energy transformation in a television. Table B3.14 in the Appendix showed that a number of school B students (34.7%) could give the multi-step of energy transformation resulting from a television. However, there were not many the school B students to give the best explanation of energy transformation

resulting from the hydro and coal generating power and clarifying the use electric energy in the lamp. Table B3.23 revealed that there were not a number of school B students (22.4 %) to be able to select the best explanation of energy transformation resulting from the hydro generating power. Table B3.24 revealed that there were not a number of school B students (24.5%) who could select the best explanation of energy transformation resulting from coal generating power. Table B3.18 revealed that there were not a number of school B students (22.4%) to understand that the amount of light energy produced from a lamp less than the amount of electric energy used. The school B students' energy test score suggested that they seemed to be only recognized the ideal concept of energy transformation. These could be viewed when they had difficulty to give the best explanation of energy transformation that needed their concerning with the energy degradation.

C. School B Students' Understanding of the Law of Energy Conservation

The exploration phase revealed that almost everyone gave descriptions of the law of energy conservation as saving of energy sources, storing up energy, and worthy energy use. The law of energy conservation is stated that total energy of an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same (Hobson, 1982). Therefore, the unit should support students to generate concept the law of energy conservation. It seemed that Teacher Kunya did not emphasize on the term of the law of energy conservation. Although the program of training of the STS energy teaching had already reminded this students' misunderstanding of the law of energy conservation, Teacher Kunya clarified the concept of the law of energy conservation but she never identified term of the law of energy conservation. This would be generated from her existing pedagogical knowledge. Generally, the former grade 9 textbook did not identify the term of the law of energy conservation but it only contained its concept.

Energy test revealed that there were not a number of students able to identify the term of the law of energy conservation. Table B3.16 revealed that approximately eight percent of school B students correctly selected the two situations that represent the concept of the law of energy conservation. According to Table B3.17, approximately fourteen percent of school B students identified that statement of “Energy is transformed from one form to another form but the total amount of energy stays the same” was the law of energy conservation. This seemed that it was consistent with how they studied in their classroom. Teacher Kunya gave her students the concept of the total amount of energy staying the same but she never identified the term. Students might make sense of concept of the law of energy conservation but they might not recognize the term because the majority of them hold the concept of energy transformation and degradation.

D. School B Students’ Understanding of Energy Degradation

The exploration phase revealed that a few school B students held existing ideas of energy degradation. It seemed that this unit enhanced their understanding of energy degradation. This could be viewed as considering to students’ ideas in the classroom activities and the energy test.

Teacher Kunya fostered students to clarify energy transformation in the thing energy use (e.g. car, electrical devices) and the generating power. But, she hardly focused on reminding students the energy spreading or any ideas of energy degradation. However, studying the electric grid system and the Num-pong power plant trip allowed students to consider waste energy that enhanced them the concept of energy degradation. Students’ discussion of the electric grid system concerned with losing electric energy when it traveled to the terminal. Students discussed as below:

Teacher Kunya: Electric energy travel from the power plant with the high voltage of electricity. Sometimes, it travels at approximately 200,000 volts. And, then it is transformed to around 20,000 volts at the transformer

substation in order to distribute electric energy for the industries, and then is transformed to 220 volts for our houses.

Nut: Why don't they initially distribute 20,000 volts? Why is 200,000 volts?

Teacher Kunya: It needs high pressure of distribution. If it is distributed a lower volt, it will be lost during traveling.

The Num-pong power plant trip gave students chances to clarify the concept of energy degradation. Students seemed to learn from the Num-pong power plant to provide information for the role-play of the Mae moh situation. Students tried to clarify the environment effects. This raised students to recognize the waste energy as discussion below:

Sa: Are there environment effects here?

The Num-pong engineers (NP): When we use the natural sources, it means that it affects the environment. If you mean the air pollution, here there is no air pollution.

Phan: Is there any waste energy in the process of generating power.

NP: Yes, it is. It always has waste energy but different kinds of energy forms depend on what process. For example, it usually wastes as heat energy. When we input 100 percent of heat energy, we never use the 100 percent of it for generating power. It must lose into the air, and then 50 – 60 percent of it is transformed into mechanical energy. ...

Energy test indicated that school B students gained their understanding of energy degradation. They recognized energy spreading in the use of energy of electrical devices and generating power. Table B3.12 in the Appendix revealed that the majority of school B students (69.4%) gave ideas that “energy can be transformed into non-useful forms of energy (e.g. waste heat)”. Table B3.14 revealed that a number of school B students (34.7%) recognized heat energy spreading when they had to select a choice that represented energy transformation in a television. And, Table B3.29 revealed that the majority of school B students (79.6%) concerned with waste heat spreading during generating power process.

However, it seemed to be a little bit confusing when students had to clarify a long step of energy transformation in a coal generating power. Table B3.23 and Table B3.24 revealed that there were not many school B students to select the description of energy transformation resulting from a coal and hydro generating power which contained heat spreading out, 22.4% and 24.5% respectively. Additionally, it seemed that they were not aware of energy spreading when the question did not ask directly clarification of energy transformation. This could be viewed when they replied the question 18 that showed in the Table B3.18. Table B3.18 revealed that there were not a number of school B students (22.4%) to think that the amount of light energy produced to lighten a lamp less than the amount of electric energy.

1.2.2 School B Students' Thinking Skills

Students' posing questions showed their thinking skills classifications. The number of posed questions in the Identification of social issues stage was counted and categorized each question by its orientation. The three question orientation attributes include phenomenon or problem description, hazards related to the problem, and treatment or solution. The proposing question in orientation of solution would be viewed as a higher level of understanding the problem than describing it, and finding treatment or solution was more positive and productive than just identifying hazards.

In sub-unit one, school B students developed their understanding the issues through group discussion. Then they posed their question to the issue of increased petrol price. Interestingly, all groups of students posed a number of oriented questions of finding treatments or solutions. There were not many the oriented questions of phenomenon and identifying hazards as showed in the Figure 4.1. Numerical and statistical details are provided in Appendix B3.1. Examples of posed questions in the orientation of phenomenon include:

What is the fossil?

What is the difference of benzene 91 and 95?

Examples of posed question orientation of identifying hazards in sub-unit one include:

What are factors run the increased petrol price?

If the petroleum runs out, what can we do?

If the government did not fix the petrol price, how will the economic be ruined now?

Examples of posed question orientation of finding treatments or solutions in sub-unit one include:

What are any strategies to decrease the price of petrol?

What don't we use other energy sources e.g. wind and water power to substitute petrol?

If the petrol price keeps growing, shall we use some renewable energy sources?

What are the energy sources that should be substituted the petrol?

Are the vegetable oil used in a car?

In sub-unit two, again, school B students posed a number of questions of solution orientation. There were not many the oriented questions of phenomenon and identifying hazards as showed in the Figure 4.1. These assumed that they held a high level of thinking skills classifications. Numerical and statistical details are provided in the Appendix B4.1. The examples of posed questions in the orientation of phenomenon include:

What is megawatt?

What are the effects of the Mae moh power plant?

Examples of posed question orientation of identifying hazards in sub-unit two include:

How long before will coal run out?

How can air pollution occur at the Mae-moh?

Why did air pollution surrounding the Mae moh power plant turn to be serious in the winter?

Examples of posed question orientation of finding treatments or solutions in sub-unit two include:

What can we do to reduce the use of coal?

Why don't they use other energy sources?

Why doesn't government construct the Nuclear power plant?

What are the strategies that should be used to eliminate the sulfur dioxide?

What should we do next to solve the problem of the Mae-moh environment damages?

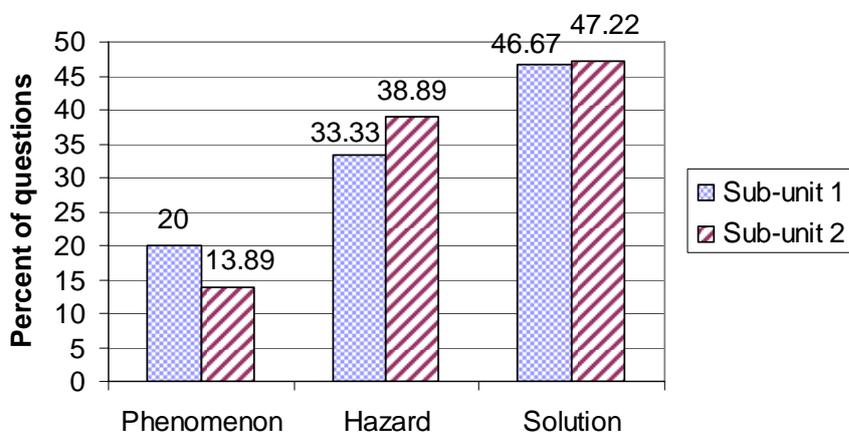


Figure 6.2 Trends in the School B Students' Question Orientation of the Sub-unit 1 and 2

According to Figure 6.2, the STS energy unit exposed students to controversial energy issues that allowed students to express their ability of thinking skills classifications. Approximately fifty percent of school B students' posing the solution oriented questions was found both in sub-unit one and two. The percentages of identifying hazards oriented questions increased from 33.33% in sub-unit one to

38.89% in sub-unit two. The percentages of phenomenon oriented question decreased from 20.00% in sub-unit one to 13.89% in sub-unit two. This suggested that the STS energy unit continually supported the development of school B students' thinking skill classification from sub-unit one to sub-unit two.

1.2.3 School B Student Decision Making about Energy Related Technological and Societal Issues

The STS energy unit raised students to select possible alternative solutions for the issues of the increased petrol price and the situation of the Mae moh situation. As a process of decision making, school B students drew their normative decision model including identifying possible way, developing criteria for decision making, validating and clarifying information and selecting alternatives. Their decision making was not only developed based on scientific knowledge but also their value judgments that were made based on societal, economical, and environmental aspects. Details are discussed below.

A. School B Students' Decision Making for the Issue of the Increased Petrol Price

Unit one allowed students to discuss the situation of the increased petrol price. Students' decision making could be viewed including (1) identify the possible alternative way, (2) clarify information, (3) evaluate the advantages and disadvantages, and (4) review the possible improvement. This normative decision making model is discussed to clarify their value judgments as following.

Firstly, students listed the possible alternative ways of action for this issue involving organizing project of energy saving, the use of alternative energy sources. The projects of energy saving include the petrol saving and a project of electric energy saving. Their ideas of the use of alternative energy sources involved bio diesel, gasohol, bio gas, biomass, and solar power.

Secondly, students clarified information for alternative ways of action. Their clarifications could be divided into two aspects including reviewing literature about scientific knowledge and doing experimentations. Students' literature review involved the petrol saving strategies, and knowledge of alternative energy. For example, the strategies of petrol saving was clarified by Kaew's group as following:

The strategies of petrol saving include 1) car pool, 2) walking or use bicycle in case of short traveling, 3) check car's engine before traveling, and 4) refuel the gasohol. (Kaew's group)

Students clarified the use of alternative energy. For example, Nok's group clarified the knowledge about gasohol. Their value clarifications were based on helping society and economical aspect. These could be viewed as their consideration of the farmers' income. As Nok's group stated:

Gasohol comprises ninety percent of benzene and ten percent of ethanol. It has 95 octanes. It can be refueled in a car. It should be promoted using widely because it may help farmer to get a higher profit. Ethanol can be produced from sugar cane and cassava. (Nok's group)

Students also clarified their information for alternative way of action by doing experiments. For example, Phan's group clarified their biogas experiments as following.

.... Material and equipment include 1) bucket for mixing water and organic matter, 2) organic matter (i.e. excrement, and leaving food), 3) pure water, and 4) a plastic tube. The methods, there are two steps. Firstly, Mix 1/3 bucket of water and 1/3 bucket of organic matter. Secondly, completely close the bucket. Leave the bucket for 7 days. After 7 days, hole the bucket, and then employ a plastic tube to connect the bucket to a gas stove. Ignite a fire, and then observe and measure thermal. ... (Phan's group)

Thirdly, students have evaluated the advantages and disadvantages their possible way of action. Students presented their projects to the classroom. Classroom discussion helped them the evaluation. Their evaluation concerned with economical aspects, helping society, and the use of local materials. For example, Nok's group realized that cassava as local material should be used to make ethanol for produce gasohol as their discussion below.

Da: Gasohol should be used more because there are the four and cassava mills in our province. Ethanol can be produced in our province.

Nok: If we use gasohol, we will help the cassava farmer to gain their profit because cassava is the material for the ethanol plant. Although there is a high cost of constructing the ethanol plant, it will be worthwhile if we compare on the direct and indirect products.

Students expressed their analysis thinking. They considered multidimensional aspects for solving problems. Traffic jams and the cost of petrol use in a car were discussed to evaluate Kaew's group campaign of petrol saving as following.

Kaew's group: Car pool is not only a strategy for petrol saving but also reducing the problem of traffic jam. There are many traffic jams in many parts of Khon Kaen city such as Malivan intersection, surrounding schools, and the bus center.

Students: I think that we must use amount of petrol when we use car pool strategies. Is it still saving petrol?

Kaew's group: Yes, it is but it is worthwhile because many people are saver than many cars.

Students' discussion for the biogas project revealed their evaluation concerning with the local material and gaining profit. Phan's group were appreciated the left-over in restaurants and the temples as their discussion below.

Students: Is it worthwhile to produce the biogas. How much does the methane result?

Phan's group: Yes, it is because we don't pay. It's free but it is not convenient. Biogas may be suitable for temples and restaurants where there is amount of left-over food. Pig farms also are suitable place. I have seen Ban Sumran Temple's biogas station. It works.

Finally, students identified possible improvement. There was only Phan's group who reviewed their improvement. Their biogas experiments suggested them to campaign people to use biogas from the excrement. As Phan's group reported:

... According to the experiment, excrement gave the biogas that produce hotter flame. The left-over food gave a little amount of biogas and produces the less hot flame than the excrement.

B. School B Students' Decision Making for the Issue of the Mae moh Situation

Unit two raised the issue of air pollution surrounding the Mae moh power plant. Students have to make decision for alternative ways of action in this situation. Their normative decision making model could be viewed including identifying possible alternatives, clarifying information known about possible alternatives, evaluating the advantages and disadvantages of alternatives, and choose an alternative. This normative decision making model is discussed to clarify their value judgments as follows.

Firstly, students identified two possible alternative ways for this situation. They considered whether the Mae moh power plant should be closed down or not.

Secondly, students clarified information about possible alternatives. They considered various kinds of generation power, and the process of generating power. Students clarified various kinds of generation for the alternatives. Each group of students presented their interesting power plants and then discussed how it had no effects to the environment. These power plants included solar, wind, nuclear, and geothermal power plant. The Num-pong power plant trip allowed them to discuss scientific knowledge about the process of the thermal generating power. It seemed that students learned from the Num-pong power plant to provide information for the Mae moh situation. Students' discussion with the Num-pong power plant engineers revealed that they tried to compare and contrast environment effects between the Num-pong and the Mae moh power plant. Students have detected the pollution that might be generated by the power plant. Students discussed as below:

Da: Are there any differences between the Num-pong and the Mae moh power plant?

Num-pong engineer (NP): ... It is quite similar. I mean the way it works. Only the fuel is used differently. The Mae moh fuel is the lignite coal but the Num-pong fuel is the natural gas. In Mae moh power plant, coal will be broken up powder, and then input furnace for boiling water.

Muay: Why does this power plant have to provide a pond of waste water?

NP: OK. In the process of generating power, we have process for cleaning equipment. The water from cleaning was contaminated with some chemical substance. So, we need that pond. We remedied the waste water to water the trees in this power plant.

The energy sources use of the power plant were clarified. They worried about the future use of energy. They tried to analyze what kinds of energy should be used, and the possible solutions in case Num-pong natural gas ran out. Students discussed as below:

Sa: If natural gas run out, what would you do?

NP: We would use diesel but it was a high capital. It might affect to cost of electric energy use. So, you need to save electric energy use.

Da: If cause of a high cost of electric energy is the using diesel in the Num-pong power plant; will you have other plans like using renewable energy or moving the power plant to other places?

NP: It is a very good question. At Num-pong, now, the pressure is low. Low pressure means that the quantity of natural gas here is decreased. But don't worry; we discovered another natural gas source at Phu Hom in Udonthani province. It is expected to supply for 50 years. So, we don't need to close down this power plant. If natural gas here runs out, we can connect pipeline from Phu Hom to here.

Technical aspects were also clarified. These included the close loop of boiling water, taking care of the generators, and distribution of electric energy. Students probed how the steam was managed as follows:

Muay: How can the power plant take the used steam out?

NP: We will not take it out. As I said earlier, it was a close loop. There, the steam will be used again and again. The close loop will be cooled to be water for reuse. However, it has a little water is lost.

Students probed the taking care of the generator as follows:

Ju: I would like to know that if the generator is old, how you will do. Are you change or fix it?

NP: Cost of a generator is 1,600 million baths.

Students: Wow!

NP: We will sell it for second hand user in Laos, Cambodia, and Myanmar.

Student raised the distribution of electric energy. Nai considered storing up a large amount of energy for high demand of electric energy as his discussion below.

Nai: When we generate a large amount of electric energy, where will we collect it?

NP: Electric energy cannot collect. We have to contribute it. We cannot store it like a battery because it is an alternate current. How can we solve this problem? We decrease the volume of generating power while people do not use a lot of electric energy.

Thirdly, they evaluated the possible alternative ways of action during role-play of the Mae moh situation. Students were separated into four groups including power plant officers, environment organization, government, and people who live in the Mae moh district. Each group received background information in each favor. They joined together to validate the advantages and disadvantages of each alternative. Their evaluation was made based on healthy, environment concerns, electric energy supply, and economic aspect. For example, students evaluated alternatives concerning with health of people living there, environment damages, and electric energy supply as following:

Da (people role): all of us got sick because of the air pollution. How will you help us?

M.C: So, how would you help them the government representative?

Tik (government role): we have given you the compensation. If it still gives the bad atmosphere, I think people should move out the Mae moh district.

M.C: Why do people need to move out? Please give them reasons.

Tik: How can you move the power plant? It will lose a large amount of money for constructing a new power plant and many factories in the northern part will be affected because no power supply.

Students raised alternative energy sources to substitute coal. Their value evaluation involved environment concerns and cost of new alternative energy sources power plant. As students discussed below:

Pron (ecologist role): the Mae moh power plant fuel is coal. Coal usually contaminated with sulfur, therefore when it was burn it would give the sulfur dioxide. When sulfur dioxide is released to the atmosphere, it affects the environment. Sulfur dioxide will affects people health. People have a chance get Numocose. Sulfur dioxide causes acid rain that makes environment damages.

Da: Why don't we close down the coal power plant and then construct a solar power plant?

Tik: I think that a solar power has no pollution but we have to pay a high cost of construction.

Finally, the majority of school B students decided to close down the Mae moh power plant. Their value clarifications concerned with environment damages, health for people living in the area, and using renewable energy sources.

1.2.4 Student School B Reaction to the Unit

School B students' responses of the Semantic Differential Scale of Students' Reaction in Energy unit (SSRE) gave an overview of their reaction to indicate their views about main activities conducted during the interventions, and to compare the STS energy unit to other science unit. Numerical and statistical details are provided in Appendix B. Students' responses of the SSRE resulted in comments overview of sub-unit 1 as showed in the Figure 6.3; overview of sub-unit 2 showed in Figure 6.4; and comparing the STS energy unit to the other science units showed in Figure 6.5.

School B students held the positive attitude toward the STS energy unit. Figure 6.3 revealed that the school B students had positive attitude towards the overview of sub-unit 1. They thought that all the main activities of sub-unit 1 quite were interesting. The activity of studying of sources of renewable energy was the most interesting. Figure 6.4 revealed that school B students had positive attitude towards the overview of sub-unit 2.

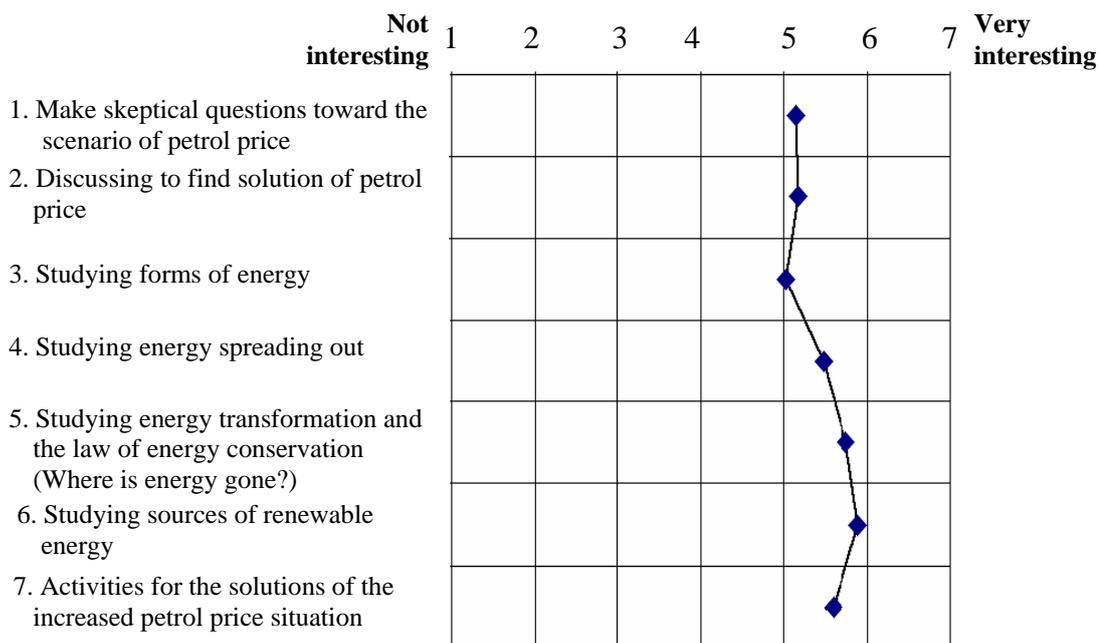


Figure 6.3 the SSRE Mean Rating School B Students to Sub-unit 1

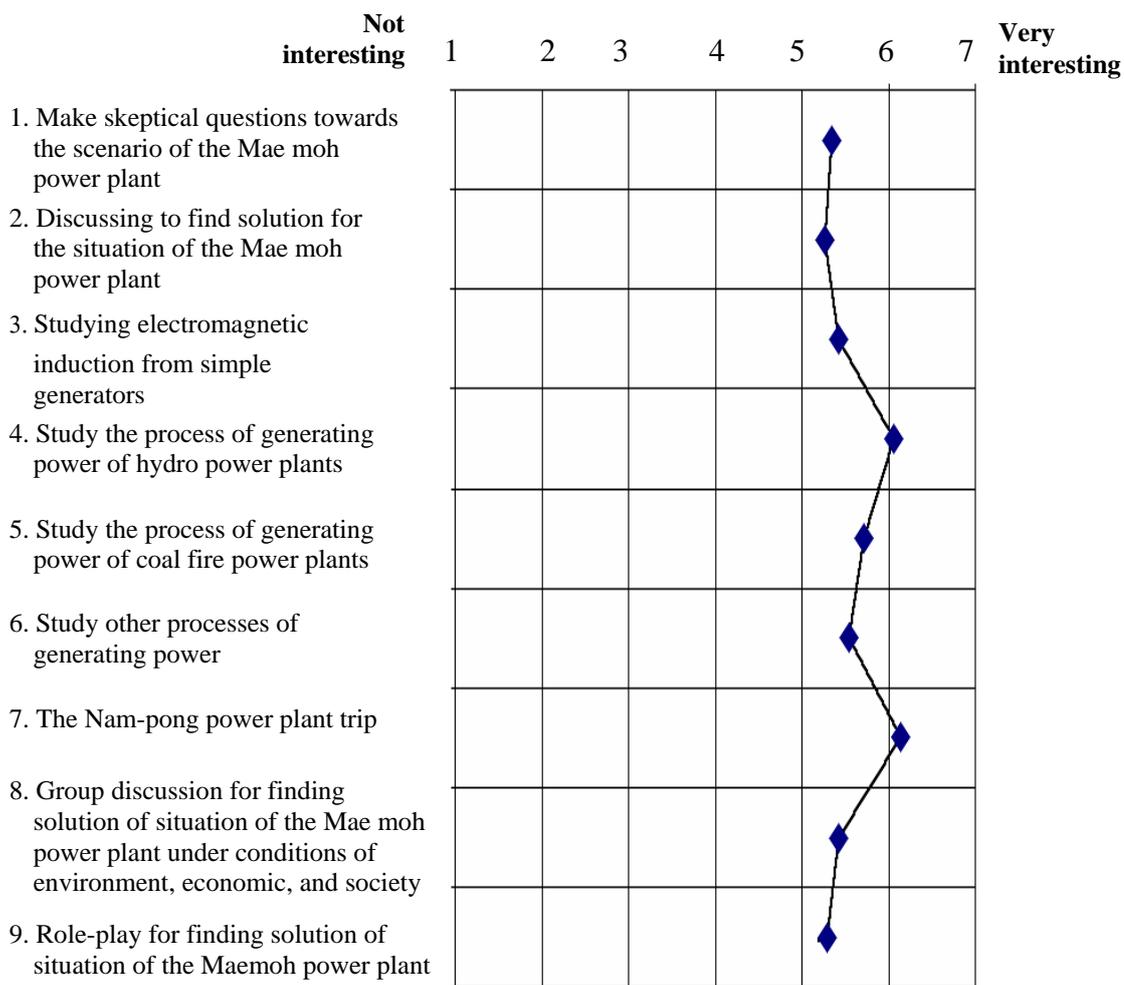


Figure 6.4 the SSRE Mean Rating School B Students to sub-unit 2

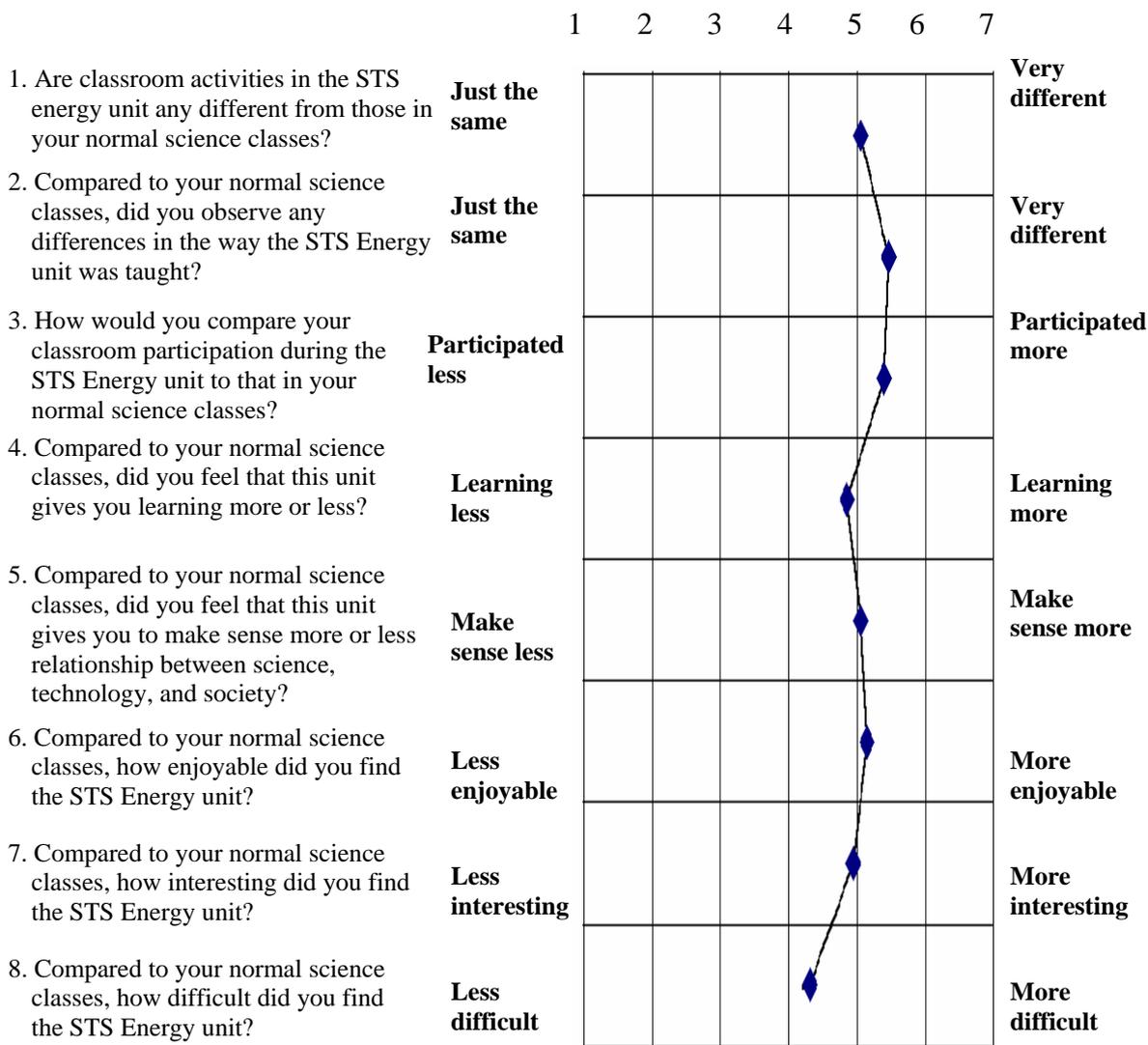


Figure 6.5 the SSRE Mean Rating School B Students to Comparison of the STS Energy Unit and Other Science Units.

They felt that all the main activities of sub-unit 2 were quite interesting. They thought that the most interesting the main activities included study the process of generating power of hydro power plants, and the Nam-pong power plant trip.

When the unit was compared to the other science unit, students felt that the STS energy unit has motivation more. Figure 6.5 revealed that school B students had more positive attitude towards the STS energy unit than the other units that they had covered in science. They felt that classroom activities and the way what they were taught were different. They more enjoyed and participated in the STS

energy classroom. They thought that the STS energy unit gave them more learning and making sense of relationship between science, technology, and society. However, it seemed that they felt that the STS energy unit was more quite difficult than their normal science unit.

1.3 Teacher school B reflection

The meeting after the intervention allowed Teacher Kunya to reflect her ideas about students' learning. Her reflection could be divided into two aspects including her ideas about students' learning, and her understanding of the STS Approach.

Kunya's reflection about students' learning revealed that she appreciated the development of students' thinking skills. Students have fun to study scientific knowledge because they have to express their ideas. Students have chance to learn energy from various sources of knowledge. She thought that the unit allowed her students to learn energy through investigation. As Kunya stated:

....The STS energy teaching and learning allowed students to express their opinion. It motivated students to investigate scientific knowledge from various sources e.g. internet and other books in library. I think that my students are happy. They had a lot of fun when they discussed in classroom. They were united to solve the problems. ..

Kunya's the STS energy teaching seemed to emphasize more discussion of social issues than studying scientific knowledge. It seemed that the attempt of solving social problems lost her energy teaching. This obviously appeared in her teaching of sub-unit two. She lacked elaboration the several kinds of the power plant, the concept of energy transformation and degradation in the power plant. Her reflection to the unit confirmed how she perceived this unit. She perceived that the unit should give students more chance to study by themselves. She wished to foster students find the

solutions of social issues from various learning sources, and to take more participation in classroom but missed to focus students the energy concepts. Kanya stated:

... Teaching the STS energy unit was easy because it allowed students to inquire knowledge from various sources of learning. Students have to find the answer by themselves. Students have taken more participation in classroom. ...

2. The School C Reflection

School C is located in a small town of Khon Kaen approximately 40 kilometres from the city of Khon Kaen. The total number of school C Grade 7 – 12 students is approximately 2,500. Ann is the participating teacher of school C. She graduated as Bachelor of Education in science for lower secondary school. Her science teaching experiences is 14 years. Ann' school load is not only science teaching but also working for the school academic affair. Her participating Grade 9 science class consists of 47 students, 25 girls and 22 boys, who live in this small town and other villages nearby this small town. Their parents work as private businessmen, government officers, and farmers. The interesting source of energy learning in the school C is the Green Classroom that provided and financially supported by the Electricity Generating Authority of Thailand (EGAT).

School C further trialing of the STS energy unit is illustrated into various aspects. These include school C students' reaction for energy learning and the unit, and teacher school C reflection to the unit. Each aspect is discussed below.

2.1 Overview of the School C STS Energy Unit Class

School C Teacher Ann interpreted the lesson plan and provided her teaching after finishing the first workshop of the provided program for teaching the STS Energy. She conducted the STS Energy teaching during early November, 2004 to early January, 2005. Her STS Energy unit consumed 9 weeks but she only spent 7

weeks, 19 hours of teaching. She lost two weeks including a week of internal school sport and another week for her educational meeting in the city, Khon Kaen province.

Starting the Identification of social issues of her sub-unit one, she allowed students to pose questions to the situation of Thai government paying for fixing petrol price. Posed questions were classified for giving information. Learning activities were provided along with posed questions including discussing and making report of renewable energy sources; activities of matching energy forms and its sources; experiments of transforming the Sun's radiation energy to heat; experiments of solar cell generating electric energy; and discussing energy use in view of the law of energy conservation, energy transformation and degradation. Ann enhanced students to present their ideas in community. Students' projects of energy saving were conducted in various ways in different samples depending on their decision making.

In sub-unit two, Ann gave students the situation of the Mae-moh and allowed students to pose questions. Posed questions were classified into groups and showed on the board. Learning activities were provided along with posed questions including discussion of grid of power system, experiments of inducing electric energy, trip to the Num-pong power plant, doing report of the power plant types, discussion of energy transformation and degradation of the Num-pong and the Mae-Moh power plant. Experiments about generating power were done in the Green Classroom that provided and financially supported by the Electricity Generating Authority of Thailand (EGAT). The activity of the socialization stage was the role-play to solve the problem of the Mae-moh situation.

2.2 School C Student Reflection

The STS Energy unit allowed students to learn a definition of energy, the law of energy conservation, energy transformation and degradation through social issues related to energy and technological aspects. School C students have not only developed their understanding of energy concepts but also critical decision makings

and thinking skills. They held also positive attitude towards the STS Energy learning. These aspects will be discussed next.

2.2.1 School C Students' Understanding of Energy Concepts.

The development of students' understanding of energy concepts were considered comparing their existing ideas before classroom intervention that was discussed in Section one of the Chapter Four. These include students' understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. Each aspect is discussed below.

A. School C Students' Understanding of Energy Sources and Forms.

Their existing ideas identified that they were confused between forms of energy and sources of energy. Providing several of energy sources for solving situation of petrol price and classifying forms of energy helped students to gain their understanding. They could distinguish forms and sources of energy. However, it seemed that some definition of energy forms still were not clear for them.

Distinction of energy forms and sources can be understandable from students matching forms and sources, giving various energy sources, and corrected final examination. All the students could give examples of matching forms of energy and sources of energy. Although some students did not communicate well, their replying to teacher probing indicates that they understood. For example:

Teacher Ann: can you give me what forms of energy are produced by those sources of energy? You can discuss within your group. I expect that everyone can tell me that those sources of energy give what all forms of energy. Saharat, can you tell me?

Saharat: chemical potential energy comes from battery and then produces electric energy.

Teacher Ann: hang on! ... So, really what form of energy was given by battery?

Saharat: It gave electric energy and chemical potential energy.

Students could clarify energy forms and sources. Forms of elastic, chemical, and gravitational potential, radiant, kinetic, and nuclear energy were given for the resulting from several sources of energy. Their energy sources given include harvesting rice, pedal a bicycle, dancing, playing, nuclear bomb, grilling and roasting, bungee jumping, and stone on cliff. Examples of students' ideas follow:

Harvest the rice, pedal a bicycle, dancing, playing and running in garden give kinetic energy. Bungee jump and a sling give the elastic potential energy. (Theera)

Grilling and roasting use radiant energy. Battery, dry cell, food, and oil give chemical potential energy. (Cathaliya)

Stone on cliff, people standing on earth and pen on the table have gravitational potential energy. Throwing ball and moving objects have kinetic energy. X-ray and radio wave have radiant energy. (Jum)

Water in damp and pen on the table have the potential energy. Heating molecule has kinetic energy. The sun gives heat and radiant energy. The sun, wind and water energy give electric energy. (Nut)

Spring and elastic band give the elastic potential energy. Nuclear bomb and radioactive isotope give nuclear energy. (Pin)

Clarifying energy forms and sources keep going when students study the power plant. For example, Teacher Ann fostered students to clarify forms of energy after finishing the trip to the Num-pong power plant. The energy sources and forms of the Num-pong power plant were clarified as follow:

Teacher Ann: before we will consider the energy transformation, could we talk about energy sources of the Num-pong power plant. What energy sources were used in the Num-pong power plant?

Students: Natural gas

Teacher Ann: Right. So, what is the resulting energy transformation?

Students: Mechanical and kinetic energy.

Teacher Ann: What energy form is resulting from the natural gas?

Students: Chemical potential energy.

It assumed that students developed their understanding of energy forms and sources. Students' responses in the energy test revealed that the majority of students could identify forms and sources of energy. These included correcting the main energy forms given from battery; recognizing the definition of kinetic and nuclear energy; and identifying sources of renewable energy and its forms. Table B3.1 in Appendix revealed that the majority of school C students (78.7%) could correctly give main forms resulting from a battery. Table B3.2 revealed that all the school C students knew that nuclear energy resulting when protons and neutrons were arranged into atomic nuclei. Table B3.3 revealed that the majority of school C students (66%) could identify kinetic energy. Table B3.6 revealed that the majority of school C students (85.1%) could classify non-renewable and renewable energy sources.

However, it seemed that students had difficulty to clarify forms of potential energy. The energy test showed that the majority of students were confused what sources of energy gave types of potential energy. Table B3.4 and B3.5 revealed that there were not a number of school C students able to identify gravitational and chemical potential energy. These might result from their missing key idea of potential energy. Potential or possible doing work was expected to be understood as key idea of potential energy but there were a few students to perceive this idea that showed in Table B3.11.

B. School C Students' Understanding of Energy Transformation

The exploration phase revealed that a number of school C students' existing ideas concerned with description of energy transformation in

generating power and using electrical devices through framework of one step and the event. Ann fostered students to clarify their description of energy transformation. For example, the energy transformation in water moving down was raised which could apply for hydro generating power later. Her students could discuss about energy transformation in water moving down as following:

Teacher Ann: the nature of energy is not only energy degradation but also transformation of energy – energy can be transformed from one form into another form. (Ann gave students example of transformation of energy in the water fall. She drew a picture as showed in Figure 6.6)

Teacher Ann: I will not consider the examples that are prepared in the sheet. Look at the picture of water moving down. Suppose, we regulate water to be not fall down to the ground.

Student: Can we regulate water?

Teacher Ann: Just suppose! ... Suppose the water stay on the cliff. What form of energy does it hold while it is going to fall down?

Student: Kinetic energy Mechanical

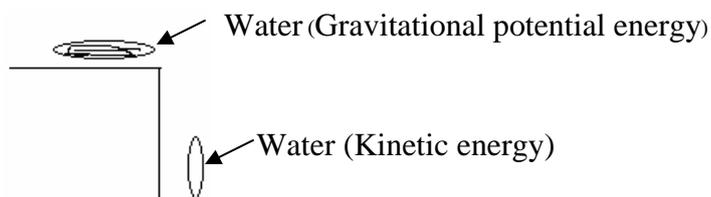


Figure 6.6 Teacher Ann's Example of Energy Transformation

Additionally, students were enhanced to develop their description to go beyond the ideal concept of energy transformation. Teacher Ann fostered students to concern other forms of energy that could spread out during the water moving down. Students could recognize that some parts of energy lost into the air. Their conversation follows:

Teacher Ann: ... Ten of ...um... unit of energy... you will study later in high level of education. Suppose I show you the slow motion of water fall.

What form of energy results while water is moving down?

Student: Kinetic energy

Teacher Ann: Is it still ten?

Students: No, it isn't

Teacher Ann: Why?

Student: ... Some parts are lost into the air.

This reflected that students recognized the concept of energy degradation when they gave description of energy transformation. Concept of energy degradation may remind students to generate their description of the multi-step of energy transformation that one form of energy always can be transformed into several forms of energy.

The experiments of the induction of electric energy and generating power allowed students to gain their understanding of energy transformation. For example, students clarified the factors resulting electric energy in a solar cell experiments. The experiment involved employing the light of a lamp to turn on a small fan. Students clarified energy transformation from the light energy to the mechanical energy as step by step as following:

Teacher Ann: What's happen when you turn down a lamp?

Student: amount of light is less than before.

Teacher Ann: What's happen with a small fan?

Student: it is slowing down.... Let me increase the light.

Students: Wow.

Teacher Ann: So, what changes?

Students: light energy change to electric energy ... and then motor energy.

Teacher Ann: What?

Students: ... mechanical energy.

Experiment of electric induction allowed students to gain insight in energy transformation of electromagnetic and electric energy. Students employed coils and magnets to induce electric energy that was indicated in the Ammeter. They clarified the factors to convert the electromagnetic into electric energy. Students discussed as following:

Student 1: Is it just a little blending? (The needle of ammeter is blending)

Student 2: The magnet is moving too slow.

Student 3: The coil is too small.

Teacher Ann: The coil must be big. The magnet also should be ...

Students: a lot of power.

Students had chance to study several kinds of power plants to find alternative solutions of the Mae-moh situation. This studying allowed students to clarify the energy transformation in various kinds of generating power. For example, students discussed the energy transformation in the hydro power plant as following.

Kay: When the water rotates the turbine, it results the mechanical energy.

Students: Heat energy was used to turn on the turbine, wasn't it?

Teacher Ann: That is used in the heat power plant like the Num-pong power plant. Your friend is reporting the hydro power plant.

Kay: Mechanical energy makes the magnets moving in order to induce electric energy.

Teacher Ann: So, how is energy transformation resulting from this generating power?

Kay: It changes from Gravitational potential energy to mechanical energy.

Water flows down the turbine and then it changes to mechanical energy when the turbine is rotated. Then, mechanical energy changes to heat and electric energy when the turbine is rotated.

The energy test showed that a number of school C students could give the best explanation of energy transformation in a television and hydro

generating power. This assumed that school C students could develop their understanding of energy transformation. Table B3.14 in the Appendix showed that the majority of school C students (38.3%) could give the multi-step of energy transformation resulting from a television. Table B3.23 revealed that the majority of school C students (49%) could select the best explanation of energy transformation resulting from the hydro generating power.

However, it seemed that a number of school C students did not recognize energy spreading when they gave description of energy transformation. This seems that they had difficulty to give the best explanation of energy transformation resulting from coal generating power and clarifying the use of electric energy in the lamp. Table B3.24 revealed that only approximately fifteen percent of school C students could select the best explanation of energy transformation resulting from the coal generating power. Table B3.18 revealed that there were not a number of school C students (25.5%) to understand that the amount of light energy produced from a lamp less than the amount of electric energy used.

C. School C Students' Understanding of the Law of Energy Conservation

Exploration phase revealed that almost everyone gave descriptions of the law of energy conservation as saving of energy sources, storing up energy, and worthy energy use. The law of energy conservation is stated that total energy of an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same (Hobson, 1982). The unit supported students to generate concept the law of energy conservation as below discussion.

Teacher Ann enhanced students to understand the law of energy conservation through concepts of energy transformation and degradation. For example, Ann discussed that energy transformation and losing some energy hinted the concept of the total energy staying the same as following:

Teacher Ann: Is all of potential energy of water transformed into kinetic energy? Can we get ten of kinetic energy?

Students: (silent)

Teacher Ann: Electricity travels from the power plant losing energy during going on the wire. Therefore, can the water spread out energy?

Students: yes, it can

Teacher Ann: is it transformed equal ten?

Students: No, it isn't

Teacher Ann: well, it doesn't equal ten because the nature of energy – energy degradation, right. Here, it may be 9.3. So, where is the rest of energy gone?

Student: it's lost into the air.

Teacher Ann: it was resisted by the air during felling down. The resisting between the water and the air produces a little of heat. This might be said that energy is degraded. It means we cannot use all of energy. Anyway, if we sum the waste heat energy and energy used, the total of energy stays the same. We can say that energy in our world and galaxy always stay the same. We cannot create new energy but we can transform energy. ...

Ann emphasized the concept of the total energy staying the same but she hardly identified term the law of energy conservation. Students might make sense concept of the law of energy conservation but they might not recognize the term. This assumption may be true. Energy test revealed that there were not a number of students able to identify term of the law of energy conservation. Table B3.16 revealed that approximately fifteen percent of school C students correctly selected the two situations that represent the concept of the law of energy conservation. According to Table B3.17, approximately twenty three percent of school C students identified the statement of “Energy is transformed from one form to another form but the total amount of energy stays the same” as the law of energy conservation.

D. School C Students' Understanding of Energy Degradation

The exploration phase reported that a number of the school C students had existing ideas of energy degradation. Their ideas included the difficulties of reusing energy, difficulties of generating power, and losing of energy. School C students seemed to find it easier gaining their understanding of energy degradation. The unit supported students to learn energy degradation as below.

Teacher Ann elaborated students' existing ideas to move towards the nature of energy. She fostered students to clarify the nature of energy. Energy spreading was viewed as the nature of energy. She always reminded students the energy spreading when they discussed the use of energy and energy transformation.

Classroom discussion revealed that students generated their understanding of energy degradation. They recognized the non-useful forms of energy. For example, they discussed about non-useful energy form in the lamp as follows.

Teacher Ann: Energy spreading. It spread out without using energy. For example, we turn on the lamp. Was all the electric energy used for the light energy?

Students: No, it wasn't.

Teacher Ann: Why not?

Students: Heat energy

Teacher Ann: That's right. We need light energy of the lamp but heat is also spreading out.

The electric grid system also was discussed about the nature of energy that could be viewed as energy degradation. They concerned with the losing of electric energy when traveled to the terminal. Classroom discussion follows:

Teacher Ann: Suppose, if the 1000 volts of electric energy is distributed from the power plant, will it arrive the terminal with the same amount as the original.

Students: It's decreased.

Teacher Ann: Suda, why is it decreased?

Suda: energy spreading out.

Teacher Ann: What is energy spreading like?

Suda: It's spreading along the wire during traveling.

Teacher Ann: Great. So, everyone look at the reading sheet of the nature of energy.

The Mae-moh situation raised students to study several kinds of the power plants to find alternative solutions. Students' description of energy transformation in generating power allowed students to recognize concept of energy degradation. For example, classroom discussion of energy transformation in hydro power plant revealed that students concerned with waste heat spreading in the turbine. Classroom discussion follows:

Teacher Ann: So, how is energy transformation resulting from this generating power?

Kay: It changes from Gravitational potential energy to mechanical energy.

Water flows down the turbine and then it change to mechanical energy when the turbine is rotated. Then, mechanical energy changes to heat and electric energy when the turbine is rotated.

Teacher Ann: How does the heat go?

Saharat: It is waste heat during the machine working. ...

Teacher Ann: You mean the generators.

Saharat: Yes. It's hot.

Energy test indicated that school C students gained their understanding of energy degradation. They recognized energy spreading in the use of energy of electrical devices and generating power. Table B3.12 in the Appendix

revealed that the majority of school C students (42.6%) gave ideas that “energy can be transformed into non-useful forms of energy (e.g. waste heat). Table B3.14 revealed that the majority of school C students (38.3%) recognized heat energy spreading when they had to select a choice that represented energy transformation in a television. Table B3.29 revealed that the majority of school C students (74.5%) concerned with waste heat spreading during generating power process. And, Table B3.23 revealed that the majority of school C students (49%) selected the description of energy transformation resulting from a hydro generating power which contained the heat spreading out.

However, it seemed to be a little bit confusing when students had to clarify a long step of energy transformation in a coal generating power. Table B3.24 revealed that only approximately fifteen percent of school C students selected the description of energy transformation resulting from coal generating power which contained heat spreading out. Additionally, it seemed that they did not aware of energy spreading when the question did not ask directly clarification of the energy transformation. This could be viewed when they replied the question 18 that showed in the Table B3.18. Table B3.18 revealed that there were not a number of school C students (23.4%) to think that the amount of light energy produced to power a lamp less than the amount of electric energy.

2.2.2 School C Students' Thinking Skills

Students' posing questions could analyze their thinking skills classifications. The number of posed questions in the Identification of social issues stage was counted and categorized each question by its orientation. The three question orientation attributes include phenomenon or problem description, hazards related to the problem, and treatment or solution. The proposing question in orientation of solution would be regarded as a higher level of understanding the problem than describing it, and finding treatment or solution was more positive and productive than just identifying hazards.

School C students were, the first sub-unit, a little confused why they needed to pose questions. They seemed to be worried the answer of those questions. They had to know what they asked. They, therefore, normally posed questions that were provided information in worksheets. Posed questions in sub-unit one were categorized into the orientation of phenomenon or problem description, for examples:

“What is fossil?”;

“How many bath has government paid to fix price of petrol below 20 bath per liter?” ;

“What year did we encounter with the situation of high petrol price?”

The examples of posed question orientation of identifying hazards in sub-unit one include:

“When will the price of petrol be higher than 20 bath per liter?”;

“What happen next, if the government stops paying money to fix oil price?”

The examples of posed question orientation of finding treatments or solutions in sub-unit one include:

“What can we do to decrease energy use?”;

“What should we do when the oil run out?”

Starting sub-unit 2, students felt free to pose questions. It was observed that they tried to pose more question. They shared their skeptical ideas of the Mae-moh situation in group. Their questions posed in sub-unit two were categorized into the orientation of phenomenon, for example:

“What province was the Mae-moh power plant located?”;

“How many watts does one megawatt equal?”;

“What is the chemical formula of sulfur dioxide?”;

- “What fuel was used in Mae-moh?”; and
- “What happened in the year 1987 and 1997?”

The examples of posed question orientation of identifying hazards in sub-unit two include:

- “How did emitted sulfur dioxide affect the environment?”;
- “What are kinds of diseases that are caused by the sulfur dioxide?”;
- “How can air pollution occur at the Mae-moh?”; and
- “What are disadvantage consequences of closing down the Mae-moh power plant?”

The examples of posed question orientation of finding treatments or solutions in sub-unit two include:

- “What should be the fuel of the Mae-moh power plant, if the lignite was used?”;
- “If you were in this situation, what would you do?”;
- “What should be the method of emitting gas from the power plant for reducing environment damages as much as we could?”; and
- “What should we do next to solve the problem of the Mae-moh environment damages?”;

Compare trend of students questions' orientation between sub-unit 1 and 2. The trends of change questions' orientations are presented in Figure 6.7. According to Figure 6.7, the percentage of phenomenon oriented question decreased from 65.12% in sub-unit 1 to 40.62% in sub-unit 2. The percentages of solution and hazard oriented questions increased from 18.6% in sub-unit 1 to 37.5% in sub-unit 2, and 16.28% in sub-unit 1 to 21.88% in sub-unit 2; respectively. This indicated that students expanded higher level of thinking skills. Huge increase in solution oriented questions indicated that students aware of seeking practical solution to a given problem rather than being fixated on requiring about risks. This suggested that

considering the alternative solution in sub-unit one stimulated students to develop their thinking skill classifications in the beginning of sub-unit two.

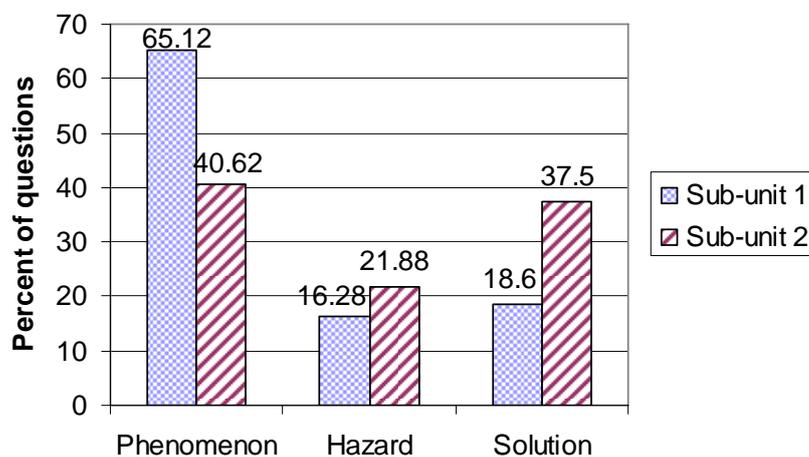


Figure 6.7 Trends in the School C Students' Question Orientation of sub-unit 1 and 2

However, the phenomenon oriented questions still remained the highest number of questions. This might root from students posing questions of which they had already known the detailed information answer. They seemed to be worried about the answer of their questions. Additionally, the total of questions increased from 43 posed questions in sub-unit 1 to 64 posed questions in sub-unit 2. Numerical and statistical details are provided in Appendix B3.2.

2.2.3 School C Student Decision Making about Energy Related Technological and Societal Issues

The STS energy unit raised students to select the possible alternative solutions for the issues of the increased petrol price and the situation of the Mae moh situation. As a process of decision making, school C students drew their normative decision model including identifying possible way, developing criteria for decision making, validating and clarification of information and selecting alternatives. Their decision making did not only develop based on scientific knowledge but also their

value judgments that were made based on the societal, economical, and environmental aspects. Details are discussed below.

A. School C Students' Decision Making for the Issue of the Increased Petrol Price

Unit one allowed students to discuss the situation of the increased petrol price. Students' decision making could be viewed including (1) identify the possible alternative way, (2) develop criteria for focus the way of action, (3) clarify information, (4) evaluate the advantages and disadvantages, and (5) review the possible improvement. This normative decision making model is discussed to clarify their value judgments as follows.

Firstly, all the students listed the possible alternative ways of action for this issue involving organizing project of energy saving. This includes projects of petrol saving and a project of electric energy saving.

Secondly, students developed criteria to focus on their alternative ways of action. Classroom discussion supported students to scope their projects. The sample group was raised in classroom discussion. Students focused on various samples including people in the town transport centre, the market, and their villages. Considering the sample suggested them find the ways of taking actions. They drew the strategies for their projects of energy saving that depended on the sample. Classroom discussion clarified the sample, for example:

Cath's group: our group plans to do the project of petrol saving. The 9 strategies for petrol saving will be present

Teacher Ann: what is your sample group? Is it only in this classroom?

Cath's group: We will paste the notice of these strategies at the village groceries.

Teacher Ann: If no one reads it, will it be a success?

Cath's group: ... we give it to the head of the village to announce our project.

And, then we will motivate people in the village by giving them the advantages.

Dear's group: we would like to motivate people in our village to decrease the village cost of electric devices. We want to show them the big change of decreasing cost.

Teacher Ann: How will you motivate them?

Dear's group: We will show them how much their use of electric energy costs during three months. Then present and ask them to follow our strategies of electric energy saving.

Thirdly, students clarified information for alternative ways of action. Their clarifications could be divided into two aspects including reviewing literature about scientific knowledge and surveying preliminary information. Students' literature review include the origin of petrol, the limitation and advantages of petrol, the energy saving strategies of other organizations, and the amount of non-renewable energy sources in Thailand. For example:

The fifty percent of energy use in Thailand is petroleum. We use it in transportation, and generation power. The petroleum is a non-renewable energy sources. It cannot be substituted when it is used. It will be run out soon. (Pron's group)

The ministry of energy proposed the ten rules for petrol saving in order to help people to manage their petrol saving. These include 1) speed limit 90 km/hr; 2) use a mass transportation; 3) stop engine during waiting for; 4) car pool; 5) avoid rush hour; 6) use telephone contact instead of fact contact; 7) plan for traveling; 8) check a tire before driving; 9) a car should not over load; 10) regularly check car engine. (Pris's group)

Students' survey for preliminary information could be viewed in Cath's group and Dear's group. Cath's group surveyed peoples' opinion about the cause of increased

petrol price and strategies of petrol saving that would be appropriate with their five villages. They concluded their survey as following:

The cause of increased petrol price includes: 1) the Iraq war, 2) the limitation of petrol in the world, 3) people did not save petrol, and 4) a high demand of petrol. The appropriate strategies of petrol saving for their five villages include: 1) speed limit 90 km/hr, 2) car pool, 3) stop engine during waiting, 4) check car engine before driving, 5) use a mass transportation. (Cath's group)

Interestingly, Dear's group aim involves people motivation by showing the big change of the village cost of electric energy. To focus their alternative taking actions, they survey of the peak of electric energy use during a day in Nong Waeng village. It was found that the peak was during 8 am – 12am. They found that a rice mill was the highest electric energy consuming that use electric energy around 33 kilowatt-hour during peak time. The example of how they collect data is showed in the Figure 6.8 According to their information, they decided to do the project of the energy saving in the rice mills. Then, Dear's group observed the rice mill working to develop Ten Rules of electric energy saving for the rice mills in their village. Their ideas concerned with the rice mill management, technique to mill the rice, and people behaviors. Their ten rules stated as below:

- (1) Restrict time to receive the rice for milling only during 7am – 12 am;
- (2) If the time out, the rest of rice will be done in a next day;
- (3) A family can mill only 1 – 2 sack of rice a day;
- (4) If a family cannot mill in the restrict time, the rice mill owner have to lend them three liter of rice;
- (5) The rice mills have to mill the newly harvested rice with the same standard;
- (6) People should go to a near by rice mill in order to be not crowded in a rice mill;
- (7) The rice should be milled only a round because of energy saving and remaining the vitamins;

- (8) In case of a mass and festivals, people should mill the rice bit by bit for storage;
- (9) The rice mills should stop running by 6 pm; and
- (10) The rice should be dried out and taken the chaff out before milling in order to save time for the rice mill working.

ปริมาณการใช้ไฟฟ้า
วันที่ 25/5.ค./48

ประเภทการใช้ไฟฟ้า	ขนาดเครื่อง (พ)	จำนวนชั่วโมง / วัน (ชม)	จำนวนหน่วยที่ใช้ / วัน
เวลา 09.00 - 12.00 ชม.			
- เครื่องสีข้าว ขนาดเครื่อง 1.5 ลิตร	1,150	9 ชม. 9	33.7
5 เครื่อง			
- เครื่องสีข้าว ขนาดเครื่อง 1/3 ลิตร	375	1/2	0.18
- พัดลมพัดตั้งพื้น 16"	55	9	0.49
รวม	4,180 กิโลวัตต์	18 ชม. 30 นาที	34.37 Unit/วัน
เวลา 12.00 - 19.00 ชม.			
- พัดลมพัดตั้งพื้น 16" 2 เครื่อง	110	6	1.32
- เครื่องสีข้าว ขนาด 1.5 ลิตร	600	1/2	0.3
- เครื่องสีข้าว 21" ธรรมดา (รุ่นเก่า)	79	1	0.079
- เครื่องสีข้าว 1.5 ลิตร	30	1	0.03
รวม	819 กิโลวัตต์	5 ชม. 30 นาที	2.21 Unit/วัน

Figure 6.8 Example of Dear's Group Data Collection of Electric Energy Use

Fourthly, students have evaluated the advantages and disadvantages their possible way of action. Their evaluation involved a survey of people's opinion. They concluded their findings that concerned with economical aspect, country development, environment concerns, and the next generation use energy. For example, Pron's group concluded the advantages and disadvantages as follow:

The advantages of petrol saving include 1) money saving, 2) government have money for the country development, 3) storage petrol for future use, 4) people become better living, 5) no more crisis of the petrol shortage, 6) the carbon dioxide resulting from a car is decreased, and 7) no traffic jam. The

disadvantages of no petrol saving include 1) waste amount of money, 2) government lose amount of money for fixing the petrol price, 3) the cost of living is increased.

Dear's group evaluated their ideas of the ten rules of electric energy saving. The rice mill owners validated their ideas. The validation allowed them to concern more economical aspects and economics. As Dear's group commented in their report:

...The rice mill owners nearly agreed with Dear's group ideas but gave them some comments. They told us that the time was too small because there were six rice mills meanwhile the village consisted of 600 families. The loading was 100 families per rice mill. ...

Finally, students identified possible improvements. There was only Dear's group who reviewed their improvement. They recognized that restricting time was not a practical idea but gaining profit was the point. As they comment in their report:

... Restricting time is not appropriate because this is a business matter. The rice mill owners have to compete with each other for gaining more profit. For example, if the Daeng rice mill runs the machine for one hour to mill the 12 buckets, he will receive around 80 Baht. If he pays 20 Baht for electric energy and 10 Baht for cost of the worn machine, his profit will be 50 Baht. If he runs the machine 5 hours during 7 am to 12 am, he will receive 250 Baht. So, if he runs the machine 11 hours during 7am to 6pm, he will receive 550 Baht at least. We realize that the restricting time is not the point, therefore, we have to improve ...

They improved their possible action that value judgment was made based on technique for gaining profit rather than restrict time. They developed their new seven rules for electric energy saving in the rice mills. Their seven rules stated:

- (1) The rice mills should be turned on the machine only a time per day;
- (2) To take care regularly the lubricant parts' machine of the rice mills;
- (3) Provide enough rice containers. Don't wait for that;
- (4) Continually input the rice while change to mill another bucket of rice;
- (5) Do not do other activities (e.g. read newspaper) that might cause to forget to input the rice;
- (6) The resistors of electrical cut out should be appropriate with the use of electricity of the motor;
- (7) Clean and check electrical system in order to prevent short-circuits.

B. School C Students' Decision Making for the Issue of the Mae moh

Situation

Unit two raised the issue of air pollution surrounding the Mae moh power plant. Students have to make decision for alternative ways of action in this situation. Their normative decision making model could be viewed including identifying possible alternatives, clarifying information about possible alternatives, evaluating the advantages and disadvantages of alternatives, and choose an alternative. This normative decision making model is discussed to clarify their value judgments as following.

Firstly, students identified two possible alternative ways for this situation. They considered whether the Mae moh power plant should be closed down or not.

Secondly, students clarified information possible alternatives. They considered various kinds of the generation power, and the process of generating power. Students clarified various kinds of the generation for alternatives after they finish studying various kinds of the generation power by doing report. Each group of students tried to propose the type of power plant that they were interested in for substitution the power plant that affected to the environment. Various types of power plants were proposed including storage water power plant, geothermal power plant,

and nuclear power plant. Their value clarification concerned with energy sources supply, pollution, safety, and scientific and technological knowledge. For example, pumped storage power plant was proposed because they were aware of water supply. As group 2 commented:

Group 2: The pumped storage power plant, pumped storage water up at high level and then let it flow down to turn the turbine. It might work even in the dry season. Did you know? Is there any energy spreading during the pumped storage power plant working?

Students: Yes, it is. Energy could spread out via the air, water, sun light and gravitational potential energy.

The geothermal power plant was raised because of their environment concerns. Students recognized that the geothermal power plant did not pollute the air as following their discussion.

Group 3: Why don't we construct a geothermal power plant at the Mae moh?

Saharat: Should you ask the Electricity Generating Authority of Thailand (EGAT)?

Group 3: So, why was the geothermal power plant constructed in the resort?

Dee: because the resort needs a fresh air.

Kay: Hey, what you asking is in the reading sheet.

Puy: Does the geothermal affect the environment damages?

Group 3: It might give the environment effect because this power plant is located in the research where fresh air is needed.

The possible alternative of the nuclear power plant was raised. However, students realized that it may impossible for Thailand when their discussion considered about the uranium supply and cost of constructing the nuclear power plant. As their discussion below:

Rin: Why doesn't Thailand construct the Nuclear power plant?

Suda: I don't know.

Teacher Ann: Any ideas?

Dee: It has a high cost of construction.

Thana: I think our country does not have technology.

Kay: Um I didn't read the reading sheet. I have no ideas ...

Jas: Nuclear power plant employ the Uranium. Are there any sources of the Uranium in Thailand?

Rin: There are in other countries such as France, Australia ...

Additionally, they clarified the knowledge about the nuclear fission and fusion reaction in order to evaluate whether it had safety or not. As their discussion below:

Thana: Why doesn't Thailand use energy resulting from the nuclear fusion reaction for generating power?

Nop: No one can control the nuclear fusion reaction.

Thana: The scientists might control it soon.

Pha: What is the difference between Nuclear fission and fusion? Does it affect the environment?

Thana: Nuclear fission reaction involves dividing of nuclei atom. When the nuclei are divided, it releases energy. Nuclear fusion reaction involves combining the nuclei of small atoms. When the nuclei are combined, it releases energy. Effects? If we provide well protection, it will not effect.

Saharat: If it is not well protected, what will be happened?

Thana: Everyone dies.

The Num-pong power plant trip allowed them to discuss the scientific knowledge about the process of thermal generating power. It seemed that students learned from the Num-pong power plant to provide information for the Mae moh situation. Students' discussion with the Num-pong power plant engineers revealed that they tried to compare and contrast environment effects between the Num-pong and the Mae moh power plant. Students discussed as below:

The Num-pong (NP) engineer: ... So, are there any questions?

Cath: Does this power plant have any environment effects?

NP engineer: Good question. Sure, it has environment effects because it uses the natural resources. Here it doesn't cause air pollution. Natural gas is used here that is clean energy. It is like your cooking gas in your home. ...

Student: Will it be similar with the Mae moh power plant?

NP engineer: It uses a different fuel. The Mae moh uses coal to boil water but here we use natural gas.

Students tried to provide their possible solutions for the Mae moh situation. Students examined the expert's idea about the problem of sulfur dioxide. Students discussed as below:

Suda: If the Num-pong power plant releases sulfur dioxide like the Mae moh power plant, how will you solve the problems?

NP engineer: The Mae moh use coal, therefore it gives the different chemical reaction from here. Here we use natural gas. It will give chemical reaction that containing carbon and nitrogen oxide. These gases were limited to contaminate in the air approximately 10 ppm but we found around here only 3 ppm. ... it is safe for environment. Our health department always survey around the power plant. They never found any decease that was caused by the pollution.

Students' discussion also allowed them to clarify the energy sources supply for the Mae moh power plant. As Thana question follow:

Thana: Well, will coal run out?

NP engineer: Yes it will. It has to run out but it depends on our use. If we use too much electric energy, it will run out soon because it cannot be substituted. It is non-renewable energy sources.

Thirdly, they evaluate the advantages and disadvantages of alternatives during role-play for finding solution of the Mae moh situation. Students were separated into four groups including the power plant officers, environment organization, government, and people who live in the Mae moh district. Each group received background information in each favor. They joined together to validate the advantages and disadvantages of each alternative. Their evaluation was made based on safety and health, environment concerns, electric energy supply for the wide area use, and the economic aspect. For example, students evaluated the effects of sulfur dioxide based on concerning with safety and healthy of people living, and environment damages as following:

M.C: Can you explain me what is the effects sulfur dioxide that you have found?

Pha (people role): We got sick as the numonicosease. Pollution from the Mae moh power plant suffocated us.

Teep (ecologist role): Sulfur dioxide result from burning the coal. It is very dangerous when it is released to atmosphere. The sulfur dioxide in the atmosphere can generate acid rain when it combines with oxygen. When the acid rain contaminates water reservoir, it might kill people if they consume that contaminated water.

Students evaluated the advantages to keep running the Mae moh power plant concerning with the electric energy supply for the wide area use. They worried about the industrial use of energy that would affect Thailand economic. The air pollution problem could be reduced. For example, students' conversation follows:

Pris (government role): if the Mae moh power plant is closed down, it will affect the wide use energy in Thailand because the Mae moh power plant distribute electricity for the northern, middle, and northeastern part of Thailand. Additionally, if the power plant is closed down, how a number of industries will also be affected. ...

M.C: If the Mae moh power plant keeps running, what will you plan to help people who live in the Mae moh district?

Pris: ... we have to set a machine to monitor the level of sulfur dioxide in the air. The lower sulfur coal should be used for generating power during winter. It might decrease the air pollution.

Finally, the majority of school C students decided to keep running the Mae moh power plant. Their value clarifications concerned with providing the large amount of electric energy supply, and the solutions of decrease air pollution. They believed that the sulfur dioxide could be confined at safe level for people and environment.

2.2.4 School C Student Reaction to the Unit

Students' responses of the Semantic Differential Scale of Students' Reaction in Energy unit (SSRE) gave the overview of their reaction to indicate their views about main activities conducted during the interventions, and to compare the STS energy unit to other science unit. These responses were rated on a 1 to 7 scale. The mean rating for each pair of words and phrases that described the classroom activities were calculated for each sample. Numerical and statistical details are provided in Appendix B. Students' responses of the SSRE gave to comment overview of sub-unit 1 showed in the Figure 6.9; overview of sub-unit 2 showed in Figure 6.10; and comparing the STS energy unit to the other science units showed in Figure 6.11.

School C students held the positive attitude toward the STS energy unit. Figure 6.9 showed that the school C students had positive attitude towards sub-unit 1. They thought that Studying sources of renewable energy and Activities of compaigned for saving energy were the most interesting. Figure 6.10 showed that the school C students had positive attitude towards the overview of sub-unit 2. They felt that activities of the Nam-pong power plant trip and Role-play for finding solution of sistance of the Maemoh power plant were the most interesting.

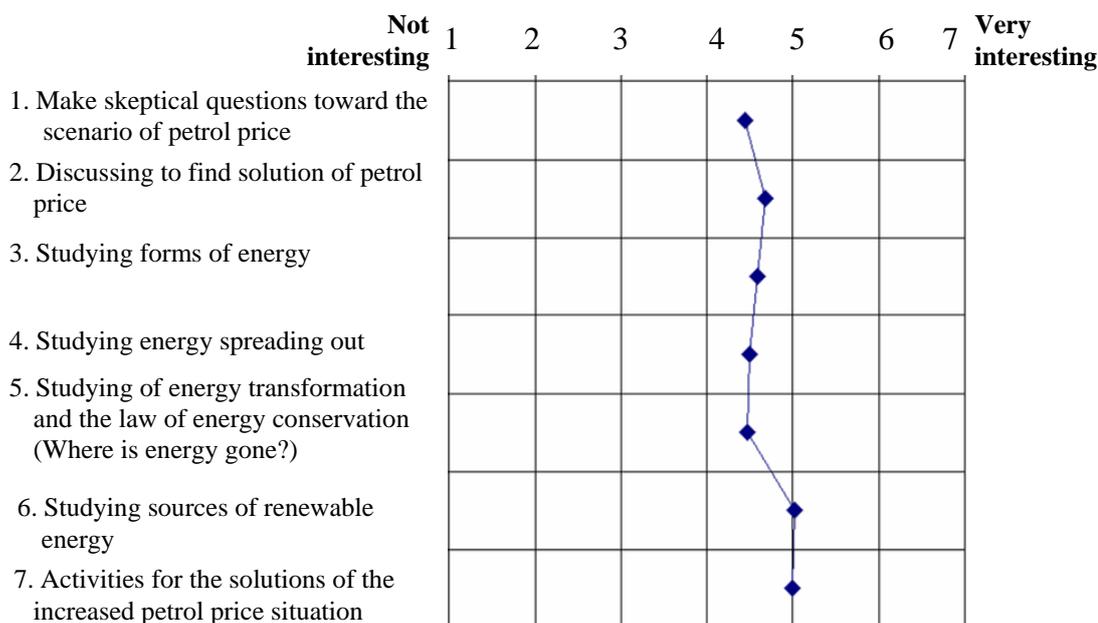


Figure 6.9 the SSRE Mean Rating School C Students to sub-unit 1

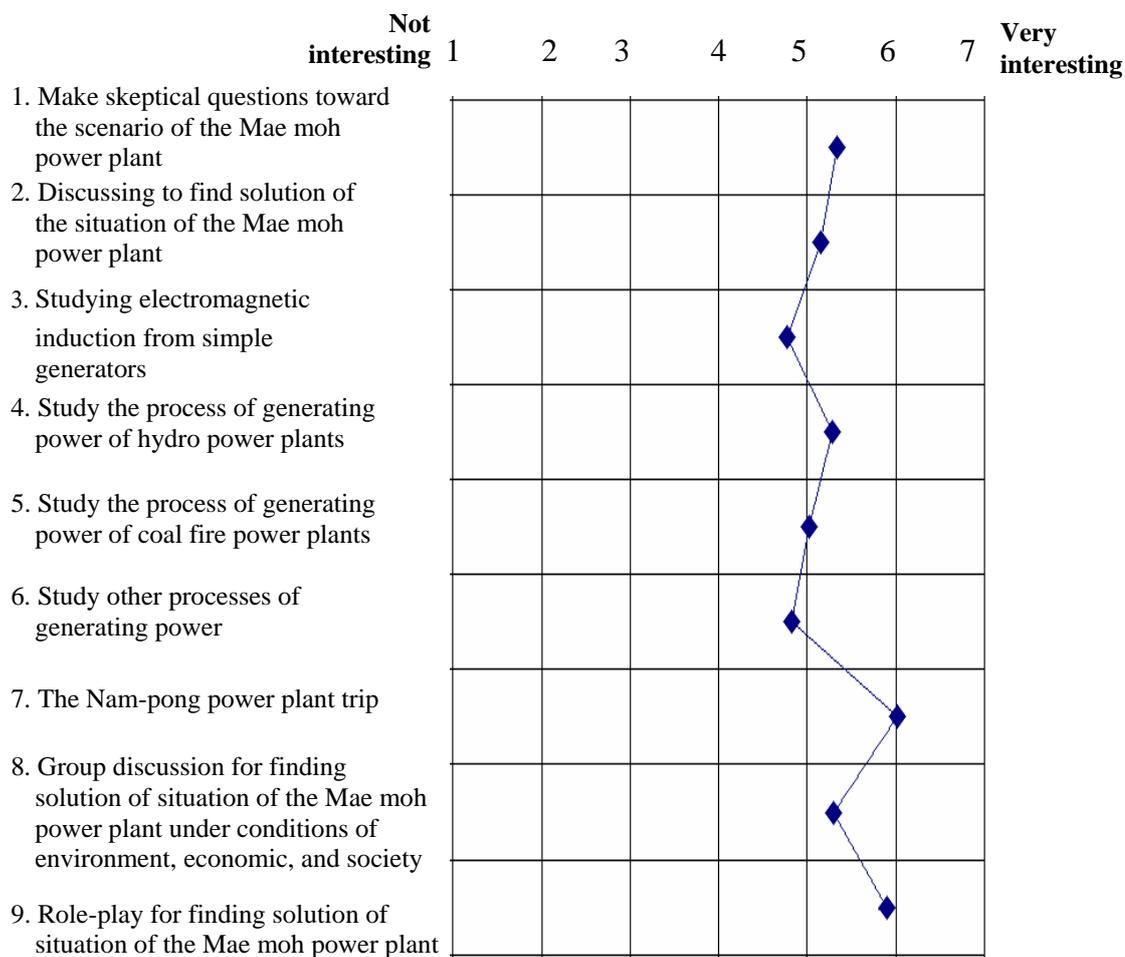


Figure 6.10 the SSRE Mean Rating School C Students to the Sub-unit 2

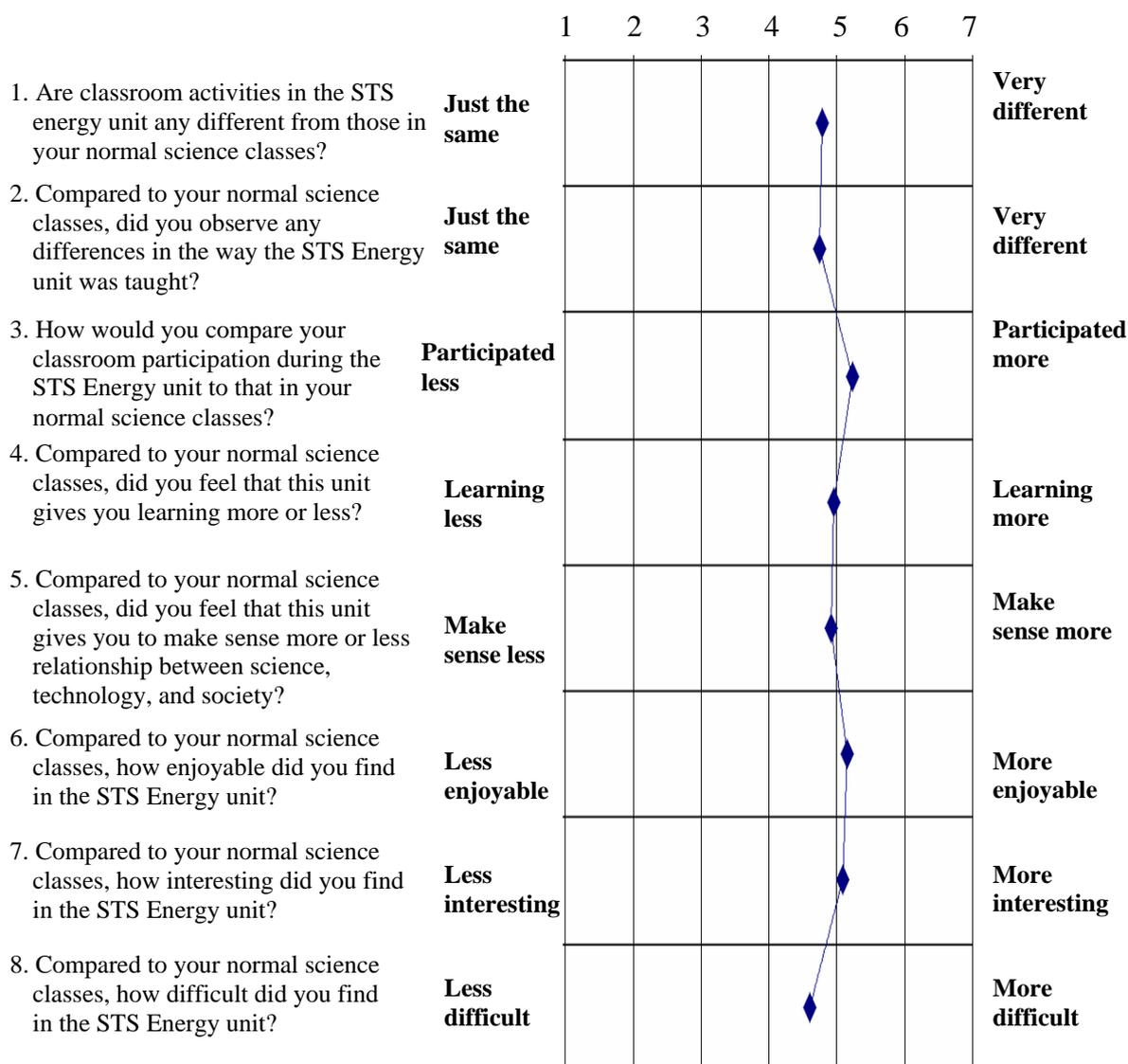


Figure 6.11 the SSRE Mean Rating School C Students to Comparison of the STS Energy Unit and Other Science Units.

When the unit was compared to the other science unit, students felt that the STS energy unit has motivation more. According to the Figure 6.11, the trends of school C students could indicate that they have more positive attitude the STS Energy unit than their normal science unit. They felt that classroom activities and the way what they were taught were different. They more enjoyed and classroom participation was higher. The STS Energy unit gave them more learning and make sense of relationship between science, technology, and society. However, they thought that learning in the STS Energy unit was more quite difficult than their normal science unit.

Observation illustrated how they were interested in the trip. students had a lot of fun, were excited, and talkative when they went to the Num-pong power station. As students' questions below:

NP engineer: That big sphere is a generator.

Students: Wow! Is it enough for a province with only a generator?

Suda: What is that?

NP engineer: It is a line for distributing electricity. It is 13.8 KV. There is copper bar inside.

Suda: How big is it?

NP engineer: It is approximately 3 inches of a diameter.

Teera: Is the turbine placed in a vertical line or a horizontal line?

Students: (laughing)

NP engineer: a horizontal line. You give a very good question. There are two styles including horizontal or radian turbine and vertical turbine. The vertical turbine will be used in the hydro power plant. The horizontal turbine will be used in the thermal power plant.

2.3 School C Teacher Reflection

Teacher Ann's reflection could be divided into two aspects including her ideas about the students' learning, and her understanding of the STS Approach and energy concepts.

2.3.1 School C Teacher's Reflection about Students' Learning

The meeting after the intervention allowed Ann to reflect her ideas about students' learning. Ann commented both the strengths and weakness of the STS energy teaching and learning.

The strengths involved enhancing students' thinking skills, students' giving ideas, investigation of scientific knowledge, and social responsibility. Ann felt

that her students gain their confidants. They were not shy to express their opinion. Ann realized that the social issues motivated students to investigate scientific knowledge and take action for their community. Ann made the following reflection:

The STS energy teaching stimulated students to investigate scientific knowledge by themselves. The unit gave students more chance to express their ideas. This helps them to gain their confidence. They were brave to give their ideas, make decision, and help society. I think that they must have sustainable scientific learning because they felt happy to learn by themselves.

However, Ann also gave the weak of the STS energy teaching and learning. She thought that the STS energy teaching and learning could not work with students who had no responsibility. As Ann commented:

If students lack responsibility, they will not gain the knowledge. Students won't do any activities. The classroom will be chaos and cannot be managed.

2.3.2 School C Teacher's Understanding of the STS Approach and Energy Concepts

Teacher Ann developed her understanding of the STS Approach and energy concepts. It seemed that Ann had gained her understanding of energy through group discussion to consider students' misconception of energy and how to solve the problem of students' misconception in the first workshop. Teachers admitted their misunderstanding of energy concepts that same as their students during teacher interview. Teachers exhibited how they increased understanding of energy concepts during giving of students' reflection in classroom.

The QTEP revealed that Teacher Ann held the misconception of the law of energy conservation. Considering students' misconception of energy suggested Teacher Ann to develop her understanding the law of energy conservation.

This could be viewed when Ann gave the concept of the law of energy conservation through energy transformation and degradation as the following conversation.

Teacher Ann: Electricity travels from the power plant losing energy during going on the wire. Therefore, can the water spread out energy?

Students: yes, it can

Teacher Ann: is it transformed equal to ten?

Students: No, it isn't

Teacher Ann: well, it doesn't equal to ten because the nature of energy – energy degradation, right. Here, it may be 9.3. So, where is the rest of energy gone?

Student: it's lost into the air.

Teacher Ann: it was resisted by the air during falling down. The resisting between water and air produces a little heat. It might be said that energy is degraded. It means we cannot use all the energy. Anyway, if we sum the waste heat energy and energy used, the total of energy stays the same. We can said that our world and galaxy energy always stay the same. We cannot create new energy but we can transform energy. ...

Teacher Ann also concerned students existing ideas about energy forms. She recognized students could have difficulty to identify the potential energy. She reminded students to be aware of key idea of potential energy that involved energy forms resulting to exist something and have potential to be transformed to other energy forms of potential ready store energy that they have readiness to work. Ann stated:

Teacher Ann: Potential energy is potentiality of energy which is stored up in something. Um..... Suppose we have ten initial of potential energy. Ten of what unit of energy... you will study later in high level of education. Suppose I show you the slow motion of water fall. What form of energy does it hold while it is moving down?

Student: Kinetic energy

Teacher Ann expresses how she developed her understanding of the STS approach when she reminded her students. She tried to illustrate her students how the social issues required scientific knowledge. Ann revised her students the social issues and the scientific knowledge that helped students to clarify information for alternative solution. For example, Ann stated:

.... According the Mae moh situation, you knew what the problem was. Although you could not real act your helping there, the Num-pong power trip would illustrate you how the power plant work and how the related problem were. You might see the difference between the Mae moh power plant and the Num-pong power plant. The Num-pong power plant did not pollute the air because it used different fuel as the Mae moh power plant. Then, we did experiment of the electric energy induction. It miniaturized the power plant and These knowledge will help you to discuss in the role-play for alternative solutions of the Mae moh situation. ...

3. The School D Reflection

The school D is located in a rural area of Khon Kaen province where far approximately 60 kilometres from the city of Khon Kaen. The total number of Grade 7 – 12 students at school D approximately includes 600. Pim is the participating teacher of the school D. She graduated as Bachelor of Education in biology. Her science teaching experiences is 10 years. Pim's school load includes biology and science teaching, head of science department, and head of school academic affair. Her participating Grade 9 science class includes 29 students, 18 girls and 11 boys, who their parents work as labor in Bangkok and farmer. The interesting source of energy learning in the school D is the solar power water pumped that is donated by an Australian organization.

School D further trialing of the STS energy unit is illustrated into various aspects. These include school D students' reaction for energy learning and the unit, and teacher school D reflection to the unit. Each aspect is discussed below.

3.1 Overview of the School D STS Energy Unit Class

School D Teacher Pim interpreted the lesson plan and provided her teaching after finishing the first workshop of the provided program for teaching the STS Energy. She conducted the STS Energy teaching during early January to late February, 2005. Her STS Energy unit consumed 8 weeks but she spent only 6 weeks, 16 hours of teaching. She lost two weeks including a week for the educational area sport, and another week for her school meeting.

The Identification of social issues of her sub-unit one, she allowed students to pose question to the situation of Thai government paying for fixing petrol price. Posed questions were classified for giving information. Learning activities were provided along with posed questions including discussing renewable energy sources; activities of matching energy forms and its sources; doing experiments of transforming the Sun's radiation energy to heat; and doing experiments of solar cell generating electric energy. Pim enhanced students to present their ideas in community. Students' projects of energy saving were conducted in various ways in different samples depending on their decision making.

Sub-unit two, Pim gave students the situation of the Mae moh and allowed students to pose questions. Posed questions were classified into group and showed in the board. Learning activities were provided along with posed questions including experiments of inducing electric energy, a trip to the Num-pong power plant, lecture the types the power plant, discussion of energy transformation and degradation of the Num-pong and the Mae-Moh power plant. The activity of the socialization stage was the role-play to solve the problems of the Mae-moh situation.

3.2 School D Student Reflection

The STS Energy unit allowed students to learn the definition of energy, the law of energy conservation, energy transformation and degradation through social issues related to energy and technological aspects. School D students have not only

developed their understanding of energy concepts but also critical decision makings and thinking skills. They held also positive attitude towards the STS Energy learning. These aspects will be discussed next.

3.2.1 School D Students' Understanding of Energy Concepts.

The development of students' understanding of energy concepts were considered comparing to their existing ideas before classroom intervention that was discussed in the Section one of the Chapter Four. These include students' understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. Each aspect is discussed below.

A. School D Students' Understanding of Energy Sources and Forms.

Their existing ideas identified that they were confused between forms of energy and sources of energy. The development of students' understanding of energy sources and forms could be clarified from their discussion in classroom and energy test score.

Pim classroom provided several energy sources for solving situation of petrol price and classifying forms of energy helped students to gain their understanding. They could distinguish forms and sources of energy. For example, students could identify various forms of energy as below:

Energy in the car engine is the chemical potential energy of petrol. The nuclear power plant uses nuclear energy. (Pha)
 The ball moving results the kinetic energy. (Phaew)
 The generator gives mechanical energy. (Dol)

Discussion in some group of students also helped them to identify forms and sources of energy, and the activities resulting forms of energy. For example, Ta's group discussed below:

Ta: Bank, you can see forms of energy in this sheet. These include potential, kinetic, heat, nuclear, and chemical potential energy. Bank, look at the car picture. What forms of energy did you know?

Bank: Electric energy in battery.

Ta: Kinetic energy results from moving. Bank, remember it.

However, it seemed that they did not clear in some definition of energy forms, particularly potential energy. For example, students hardly identified chemical potential energy. They only mentioned that energy from the petrol or the kinetic energy of the oil. This could be viewed when students clarified energy transformation as below.

When the car is running, the kinetic energy of the oil changes to the kinetic energy of the pistol and the car. (Aom)

The car uses the energy from the petrol. The petrol comes from the petrol source under the ground. ... (Dol's group)

Students' responses in the energy test revealed that the majority of students could identify forms and sources of energy. It assumed that students developed their understanding of energy forms and sources. These included correcting the main energy forms given from battery; recognizing the definition of kinetic and nuclear energy; and identifying sources of renewable energy and its forms. Table B3.1 in Appendix revealed that the majority of school D students (44.9%) could correctly give main forms resulting from a battery. Table B3.2 revealed that the majority of school D students (51.7%) knew that nuclear energy resulting when protons and neutrons were arranged into atomic nuclei. Table B3.3 revealed that the majority of school D students (44.9%) could identify kinetic energy. Table B3.6 revealed that the majority of school D students (44.9%) could classify non-renewable and renewable energy sources.

Again, it seemed that students had difficulty to clarify forms of potential energy. The energy test showed that the majority of students were confused

what sources of energy gave types of potential energy. Table B3.4 and B3.5 revealed that there were not a number of school D students to be able to identify gravitational and chemical potential energy. These might result from their missing key idea of potential energy. Potential or possible doing work was expected to understand as key idea of potential energy but there were a few students (6.9%) to perceive this idea as showed in Table B3.11.

B. School D Students' Understanding of Energy Transformation

The exploration phase revealed that the majority of school D students' existing ideas concerned with description of energy transformation in generating power through framework of multi-step. This indicated that they would be easier to develop understanding of energy transformation. However, their descriptions of energy transformation in using electrical devices were clarified through the framework of one step and event.

To gain students' understanding of energy transformation, Teacher Pim fostered students to clarify their description of energy transformation during the studying energy sources and the generating power. For example, students clarified the energy transformation for the radiant energy of the sun during doing their experiment of solar cell as students' discussion below:

Dol: The solar cell will change the radiant energy of the sun to the electric energy

Teacher Pim: Is it only changed into the electric energy? If I place a banana in the outdoor plastic house, is the radiant energy of the sun changed into the electric energy?

Dol: No, it isn't. It changes to heat energy.

Teacher Pim: Would the solar cell change the radiant energy to only the electric energy?

Students: No.

Energy transformation in the generating power was also clarified. The various kinds of power plants were clarified. Students could describe energy transformation in the hydro and coal power plant as step by step but the potential energy of water was hardly identified as students reported below:

....The dam could generate electricity. Water power is used for turning turbine in order to generate electric energy. It is energy transformation of water power to mechanical and electric energy. ... (Ta)

... The coal power plant uses energy from coal to generate the power. Coal boiled the water. The chemical potential energy is transformed into the heat energy. Then, the steam flows through the turbine for turning the turbine. This involves kinetic energy is transformed into the mechanical and electric energy. (Pha)

However, it seemed that the problem of identifying sources and forms of energy affected their understanding of energy transformation. For example, students' tracing back energy forms illustrated how the problem of the chemical potential energy of petrol affected their clarification of energy transformation.

Example:

The car uses energy from petrol. Petrol comes from petrol source under the ground. ... (Dol's group)

The car uses energy from petrol. The petrol is produced from the coal. (Wat's group)

The energy test showed that a number of school D students could give the best explanation of energy transformation in a television and coal generating power. This assumed that the school D students could develop their understanding of energy transformation. Table B3.14 in the Appendix showed that the majority of school D students (62.1%) could give the multi-step of energy transformation resulting from a television. Table B3.24 revealed that the majority of school D students (34.5%) could select the best explanation of energy transformation resulting

from the coal generating power. A number of students' giving the best explanation of coal power plant would be consistent with their paying attention in the generating power process of the Num-pong power plant that was similar process of generating power to the coal power plant. School D students were more questioning in the Num-pong power plant than in regular their science classroom.

However, it seemed that a number of school D students did not recognized energy spreading when they gave description of energy transformation. This seemed to be caused that they had difficulty to give the best explanation of energy transformation resulting from the hydro generating power and clarifying using electric energy in the lamp. Table B3.23 revealed that only approximately seventeen percent of school D students could select the best explanation of energy transformation resulting from hydro generating power. Table B3.18 revealed that only approximately seventeen percent of school D students understood that the amount of light energy produced from a lamp less than the amount of electric energy used.

C. School D Students' Understanding of the Law of Energy Conservation

The exploration phase revealed that almost everyone gave descriptions of the law of energy conservation as saving energy sources, storing up energy, and worthy energy use. The law of energy conservation is stated that total energy of an isolated system always stays the same. That is, energy cannot be created or destroyed; energy can be transformed from one form to another, but the total amount of energy stays the same (Hobson, 1982). Therefore, the unit should support students to generate concept the law of energy conservation. It seemed that Teacher Pim did not emphasize the term of the law of energy conservation. Although the program of training of the STS energy teaching had already reminded this students' misunderstanding of the law of energy conservation, Teacher Pim clarified the concept of the law of energy conservation but she never identified the term of the law of energy conservation. This would be generated from her existing pedagogical

knowledge. Generally, the former grade 9 textbook did not identify term of the law of energy conservation but it only contained its concept.

Energy test revealed that there were not many of students able identify term of the law of energy conservation. Table B3.16 revealed that there were not many school D students (24.1%) to correctly select the two situations that represent the concept of the law of energy conservation. According to Table B3.17, approximately fourteen percent of school D students identified that the statement of “Energy is transformed from one form to another form but the total amount of energy stays the same” was the law of energy conservation. This seemed that it was consistent with how they studied in their classroom. Teacher Pim gave her students the concept of the total energy staying the same but she never identified the term. Students might make sense concept of the law of energy conservation but they might not recognize the term because the majority of them hold the concept of energy transformation and degradation.

D. School D Students’ Understanding of Energy Degradation

The exploration phase revealed that a few school D students held existing ideas of energy degradation. It seemed that this unit enhanced their understanding of energy degradation. This could be viewed as considering to students’ ideas in the classroom activities and the energy test.

Teacher Pim usually reminded students to recognized waste energy during students’ clarification of energy transformation. This supported students’ discussion in group to identify forms of energy that could be waste energy. For example, students tried to identify waste energy in the electrical devices as follow.

Ta: Is there energy that we don’t want resulting from a fan? ...

Paew: Electric energy

Bank: Everything is the same. It gives heat as waste energy. We want only the wind but it also gives us the heat behind it.

Ta: Heat? ... It may not only the heat. ... Help to think of others.

Students' clarification of using electrical devices for hours, and where energy is gone illustrated how they understood energy degradation. For example, students had described what happened when the lamp was used for 10 hours. Their descriptions reflected that they recognized the heat energy spreading during energy transformation. As some groups of students reported:

When we turn on the lamp, the electric energy will be transformed into light energy. When the lamp has turned on for a while, the lamp is heating. The lamp lets heat into the surrounding. (Pha's group)

When the lamp has turned on for long time, the heat energy will appear. It is wasted energy use. (Kum's group)

Clarification of where energy is gone also reflected students to make sense of energy degradation. For example, students described that energy was not gone but it just was transformed into other forms of energy. Their descriptions concerned with non-useful forms of energy e.g. waste heat. As some group of students reported:

While a ball is moving down hill, it has the kinetic energy. When a ball has come to the flat floor, and then it stop, where is the kinetic energy gone? The kinetic energy was not gone but it is transformed into other forms that we didn't recognize because it was non-useful forms of energy. (Pha's group)

When we use a blender, where is the electric energy gone? Energy is not gone, it is used for turning motor and heat of motor and fruit. It is energy transformation of electric energy to mechanical energy. (Dol's group)

Energy test indicated that school D students gained their understanding of energy degradation. They recognized energy spreading in the use energy of electrical devices and generating power. Table B3.12 in the Appendix

revealed that the majority of school D students (41.4%) gave ideas that “energy can be transformed into non-useful forms of energy (e.g. waste heat). Table B3.14 revealed that the majority of school D students (62.1%) recognized heat energy spreading when they had to select a choice that represented energy transformation in a television. Table B3.29 revealed that the majority of school D students (41.4%) concerned with waste heat spreading during generating power process. And, Table B3.24 revealed that the majority of school D students (34.5%) selected the description of energy transformation resulting from coal generating power which contained heat spreading out.

However, it seemed to be a little bit confusing when students had to clarifying a long step of energy transformation in coal generating power. Table B3.23 revealed that only approximately seventeen percent of school D students selected the description of energy transformation resulting from a hydro generating power which contained heat spreading out. Additionally, it seemed that they were not aware of energy spreading when the question did not ask directly clarification of the energy transformation. This could be viewed when they replied the question 18 that showed in the Table B3.18. Table B3.18 revealed that there were not a number of school C students (17.2%) to think that the amount of light energy produced to power a lamp less than the amount of electric energy.

3.2.2 School D Students' Thinking Skills

Students' posing questions could analyze their thinking skills classifications. The number of posed questions in the Identification of social issues stage was counted and categorized each question by its orientation. The three question orientation attributes include phenomenon or problem description, hazards related to the problem, and treatment or solution. The proposing question in orientation of solution would be considered as a higher level of understanding the problem than describing it, and finding treatment or solution was more positive and productive than just identifying hazards.

In sub-unit one, school D students developed their understanding of issues through group discussion. Then they posed their question to the issue of the increased petrol price. It seemed that they tried to make the questions from the provided information rather than from their skeptical views. This resulted that there were a number of posed questions in the orientation of the phenomenon or problem description but there were few posed questions in the orientation of the identifying hazards, and the finding treatments or solutions as showed in the Figure 4.11. Numerical and statistical details are provided in Appendix B4.3. The examples of posed questions in the orientation of phenomenon include:

- How much has the government paid for fixing the petrol price since the 10th January until 17th June 2004?
- What does the word of the fixing the petrol price mean?
- How does the petrol involve the oil?
- Where oil discovered first?

The examples of posed question orientation of identifying hazards in sub-unit one include:

- If the government does not longer fix the petrol price, how will Thailand economic be?
- The increased petrol price affects the goods price and cost of electricity. So, what is next?
- If the government does not longer fix the petrol price, what will be happened?

The examples of posed question orientation of finding treatments or solutions in sub-unit one include:

- If oil runs out, what energy sources should be substituted?

In sub-unit two, Teacher Pim reflected students to make questions requiring analysis or applications. She reminded her students to decrease the

questions that had explicitly known answers. This fostered the school D students to make a number of the questions in the orientation of the hazards and the solutions as showed in Figure 6.12. Numerical and statistical details are provided in the Appendix B3.3. School D students posed the question orientation of phenomenon in sub-unit two, for example:

What are the causes of the 1st – 3rd the Mae-moh power plant generator stopped running?

How many megawatts does a generator produce?

How many years have the Mae-moh power plant run?

The examples of posed question orientation of identifying hazards in sub-unit two include:

What are the environment effects of sulfur dioxide?

Why does the Mae-moh power plant hurt a number of people surrounding the Mae-moh district?

Mae-moh power plant released sulfur dioxide polluting the air? What else pollutes the air?

If we have no longer the Mae-moh power plant, how will we have enough electric energy use?

Examples of posed question orientation of finding treatments or solutions in sub-unit two include:

How can the government solve the problem of the Mae-moh situation?

If the coal runs out, what energy sources should be used?

What other energy sources should be used in the Mae-moh power plant?

How will we protect and solve the problem of air pollution?

What are the strategies that should be used to eliminate sulfur dioxide?

According to the Figure 6.12, it assumed that the STS energy unit exposed students to controversial energy issues that advocated students to develop their ability of thinking skills classifications. The percentages of phenomenon oriented question decreased from 63.64% in sub-unit one to 34.15% in sub-unit two. The percentages of hazard oriented questions stay quite the same. The percentages of solution oriented questions increased from 6.06% in sub-unit one to 34.15% in sub-unit two. A Huge increase of the solution oriented questions indicated that school D students expanded higher level of thinking skills. They gained more seeking practical solution to a given problem rather than being fixated on requiring about risks. This suggested that the STS energy unit continually supported the development of school D students' thinking skill classification from sub-unit one to sub-unit two.

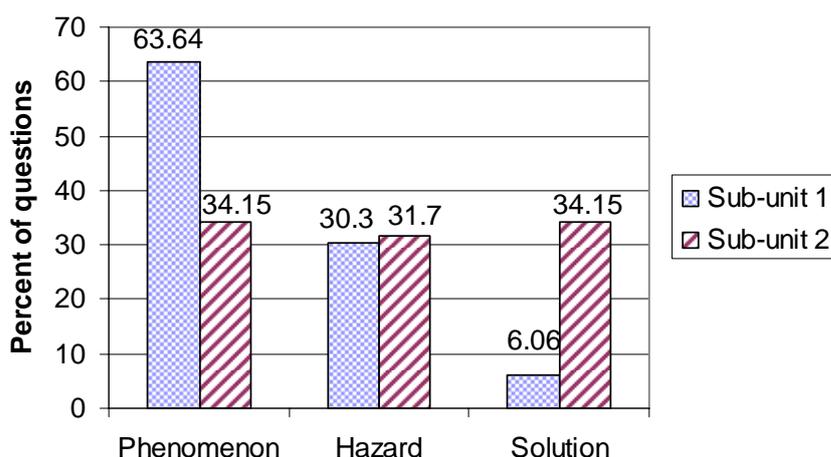


Figure 6.12 Trends in the School D Students' Question Orientation of the Sub-unit 1 and 2

3.2.3 School D Student Decision Making about Energy Related Technological and Societal Issues

The STS energy unit raised students to select the possible alternative solutions for the issues of the increased petrol price and the situation of the Mae moh situation. As a process of decision making, the school D students drew their normative decision model including identifying possible way, developing criteria for

decision making, validity and clarify of information and selecting an alternatives. Their decision making were not only developed based on scientific knowledge but also their value judgments that were made based on the societal, economical, and environmental aspects. Details are discussed below.

A. School D Students' Decision Making for the Issue of the Increased Petrol Price

Unit one allowed students to discuss the situation of the increased petrol price. Students' decision making could be viewed including (1) identify the possible alternative way, (2) clarify information, (3) evaluate the possible way of action, and (4) select their alternative action . This normative decision making model is discussed to clarify their value judgments as following.

Firstly, students listed the possible alternative ways of action for the issue of the increased petrol price involving organizing project of energy saving, the renewable energy sources use. For example:

- Use renewable energy in our country;
- Organize campaigns for energy saving;
- Organize campaigns for using renewable energy;
- Gain more profit petrol use

Secondly, students clarified information known for alternative ways of action. Their clarifications could be divided into two aspects including what they were supposed to do and review the related knowledge. Students clarified their planning what their work and who will take responsibility on. For example, students discussed as follows:

Karn: Could we make a slogan board about electric energy saving.

Ta: Where will we attach this slogan board?

Karn: ...what about the toilet and along the stair of each building.

Su: So, what will be written? I have no any ideas. So, if you know, I will OK.

Ta: Um... I will find it.

Students also discussed the related knowledge that should be provided. Many students had no ideas. They tried to identify knowledge from the media. For example, students discussed as follows:

Aom: what words should be written in the small board to bind around the trees in our school?

Pla: They should be like: speed limit 90 km/hr, car pool, stop engine during waiting, check car engine before driving. Like, they are announced on TV.

Aom: I think we should rewrite it like a slogan or poem.

Dol: We have to find something like details for energy saving.

Naree: what is it about?

Dol: It should be the effects of using too much petrol and electric energy.

Thirdly, students have evaluated their possible way of action. Their evaluation involved the tactical strategies of energy saving campaign. For example, Dol's group concerned with students' value of listening the songs. They planed to organize the school radio song program with inserting the strategies of energy saving. Dol explained:

Researcher: Why would your group like to organize the school radio program about the energy saving?

Dol: It can reach to everyone. If we do the slogan board, we cannot promote this campaign to everyone.

Researcher: Why did you think that everyone listens your radio program?

Dol: They like the song program. Our program will provide good songs and the details of energy saving.

The tactic of time was concerned for Pla's group. They believed that their persuasion about petrol saving would achieve if they allowed people to see in one's mind's eye.

As Pla explained:

Researcher: Why would your group like to campaign petrol saving through binding the slogan board around the tree?

Pla:a slogan board will tell everyone anytime.

Finally, students selected their alternative action. All the groups of the students selected to do the activities related to the campaign of the petrol and electric energy saving in their schools.

B. School D Students' Decision Making for the Issue of the Mae moh Situation

Unit two raised the issue of air pollution surrounding the Mae moh power plant. Students had to make decision for alternative ways of action in this situation. Their normative decision making model could be viewed including identifying possible alternatives, clarifying information known about possible alternatives, evaluating the advantages and disadvantages of alternatives, and choose an alternative. This normative decision making model is discussed to clarify their value judgments as follows.

Firstly, students identified two possible alternative ways for this situation. They considered whether the Mae moh power plant should be closed down or not.

Secondly, students clarified information possible alternatives. They considered various kinds of the generation power, and the process of generating power. Students clarified various kinds of generation for the alternatives. Each group of students presented their interesting power plants and then discussed how it had no effects to the environment. These power plants included the solar, wind, nuclear, and

geothermal power plant. The Num-pong power plant trip allowed them to discuss the scientific knowledge about the process of the thermal generating power. It seemed that students learned from the Num-pong power plant to provide information for the Mae moh situation. Students' discussion to the Num-pong power plant engineers focused on technical process of the generating power, budget, alternative energy sources, and environment concerns. Technical process of generating power was clarified, for example, students wondered how the steam could generate power, compared fuels generating power, and considered alternative energy sources use in case of the natural gas and diesel running out. As students' discussion below:

Na: Which one will be better if we compare between diesel and natural gas?

Num-pong engineer (NP): If we consider the capital, natural gas is better. If we consider the value of thermal, diesel is better.

Aom: How is steam used for generating power?

NP: It is used for turning turbine because the steam gives both temperature and pressure. The pressure can turn the turbine like the water flow through the turbine.

Korn: If natural gas and diesel runs out, what will be substituted?

NP: Our power plant was not designed for using other fuels. If there are not these two kinds of energy sources, it can do nothing. However, now, we found another natural gas source at the Phu hom in Udonthani province which would supply for many years.

Students also concerned with economical aspects. For example, they clarified the budget for generating power as the students' discussion as below.

Naree: I would like to know how much budget is used for generating power.

NP: Natural gas was bought as thermal value. One thousand million cubic meters of natural gas was used here that it was approximately 200 – 300 million Baht a month. ...

Dol: Cost of diesel is so expensive. Why don't you use only the natural gas?

NP: Only natural gas is not enough for generating power. Here we need around 120 million cubic feet of natural gas a day but the PTT gave us only 33 million cubic feet of natural gas.

Students' clarification revealed their environment concerns. They probed the generating power that could cause environment effects. For example, they focused on the high temperature emitted air that could affect the environment. As students' discussion below:

NP: The cooler tower will let heat off. Its temperature is around 110 degree centigrade that there are no effects to the environment.

Na: How much will it affect to the environment?

NP: If it over 200 degrees centigrade, it might affect to the environment.

Thirdly, they evaluated the possible alternative ways of action during role-play of the Mae moh situation. Students were separated into four groups including the power plant officers, environment organization, government, and people who live in the Mae moh district. Each group received background information in each favor. They joined together to validate the advantages and disadvantages of each alternative. Their evaluation was made based on safety and health, environment concerns, electric energy supply, and the economic aspect. The people's safety and healthy were raised for the most important criteria for solving this problem. The Mae moh people favor presented the three proposals for the alternatives. Their proposals were made based on people's health concerns. However, their proposals were balanced with budget available. As students' discussion below:

Na: Um ... As the Mae moh people representative, I give the power plant officers the three proposals to solve this problem. Can you select one for solving our problem? First, move away the power plant. Second, keep running the power plant with no pollution. Third, if the power plant still be here, government has to give people money to medicine year long their sick as much as they need until their recovering.

Jit: For the first proposal, I afraid that the government will not have enough money for us.

Pla: If we need to move the power plant to a new place, I think it should far away the communities.

It seemed that the people health are the central ideas of school D students to clarify alternatives for the Mae moh situation. The people health issues were clarified nearly overall the session of the role-play. For example, students discussed as following:

Na: I think that the continually curing sickness is the most important taking responsibility for the power plant. People wish the year long curing until they recover.

Ta: If the power plant still be here, you will never recover.

Jit: We also would like to move to a new place far from communities.

Environment concerns were also applied for evaluating the possible alternatives. Students were aware of decreasing pollution. They proposed the possible actions to decrease the pollution problems. These included alternative energy use, the waste water treatment, and electric energy saving. Students clarified waste water treatment to solve the environment effects to the water. As students' discussion follow:

Aom: The power plant gave many effects to the environments. The water also is affected. How can we solve the problem of the water? Does the ecologist have any ideas?

Ta: I think we can treat the waste water. The process of the waste water treatment consists of 4 processes. 1) Physical process, it separates solid matter away from water. 2) Chemical process, it involves eliminating the compound substances. 3) Biological process, it involves eliminating an organic substances. And, 4) physical and chemical process, it involves eliminating an inorganic substances e.g. absorption, and the charge exchanging.

Finding alternative energy sources, with no pollution effects, were considered. Students tried to identify the energy sources that gave no pollution. An available sources and its price were evaluated for possible alternatives. As students' discussion below:

Ta: Why don't you employ other energy sources that don't have pollution?

Jit: Diesel is expensive for generating power. Coal is easy to find and so cheap.

Ta: What about the natural gas?

Jit: There is not enough the natural gas for the Mae moh power plant. The Mae moh power is so big. It is bigger than the Num-pong power plant.

Additionally, the electric energy saving was raised in order to decrease the air pollution. As Korn stated:

Korn: As government representative, we think that everyone should save electric energy. If we all save electric energy, air pollution from the power plant will also decrease.

Finally, the majority of school D students decided to keep running the Mae moh power plant. Their value clarifications concerned with providing the large amount of electric energy supply, and the solutions of decrease air pollution. They believed that the sulfur dioxide could be confined at a safe level for people and environment.

3.2.4 School D Student Reaction to the Unit

School D students' responses of the SSRE gave the overview of their reaction to indicate their views about main activities conducted during the interventions, and to compare the STS energy unit to other science unit.

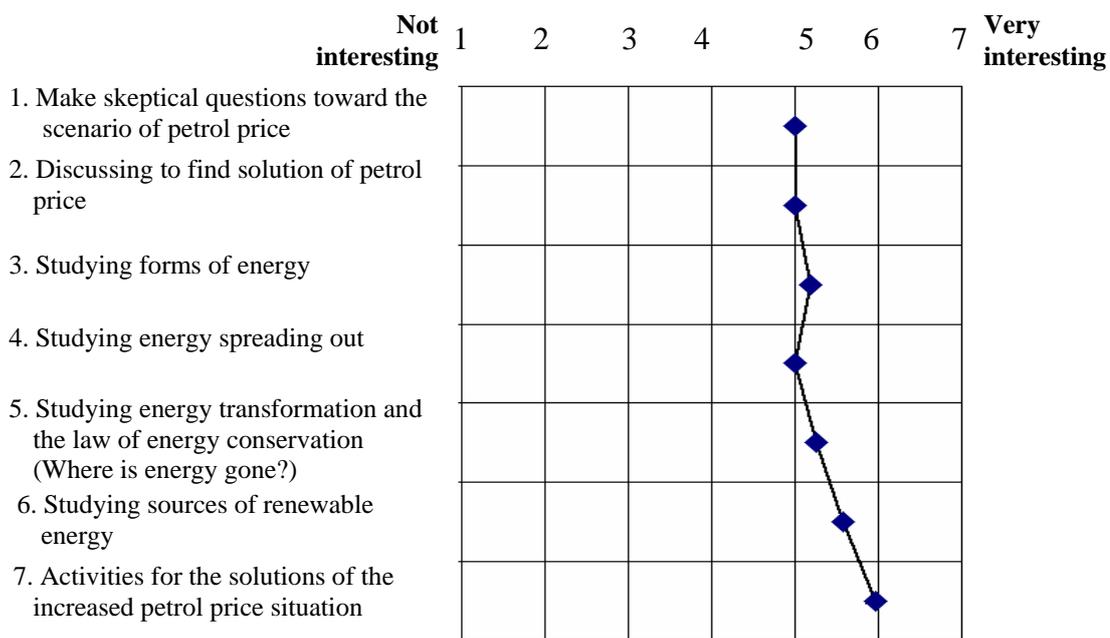


Figure 6.13 the SSRE Mean Rating School D Students to Sub-unit 1

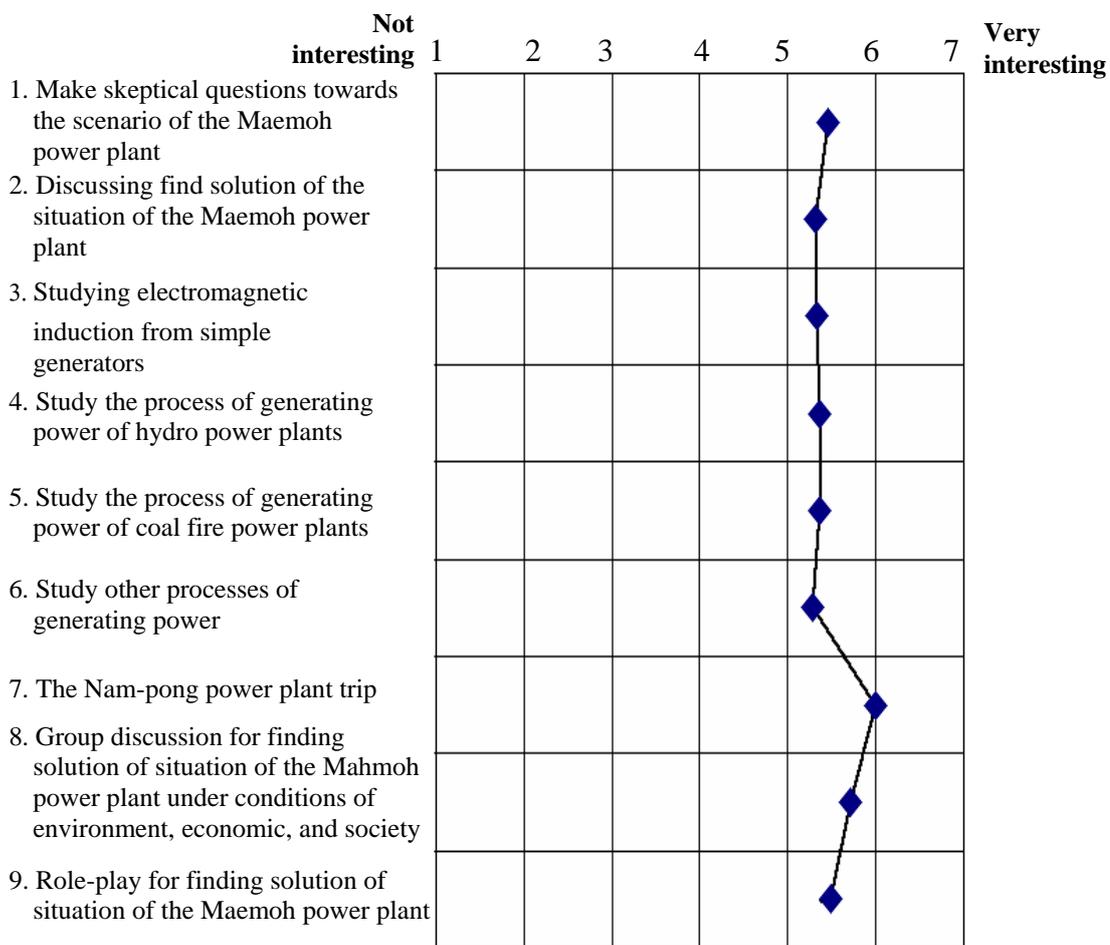


Figure 6.14 the SSRE Mean Rating School D Students to the Sub-unit 2

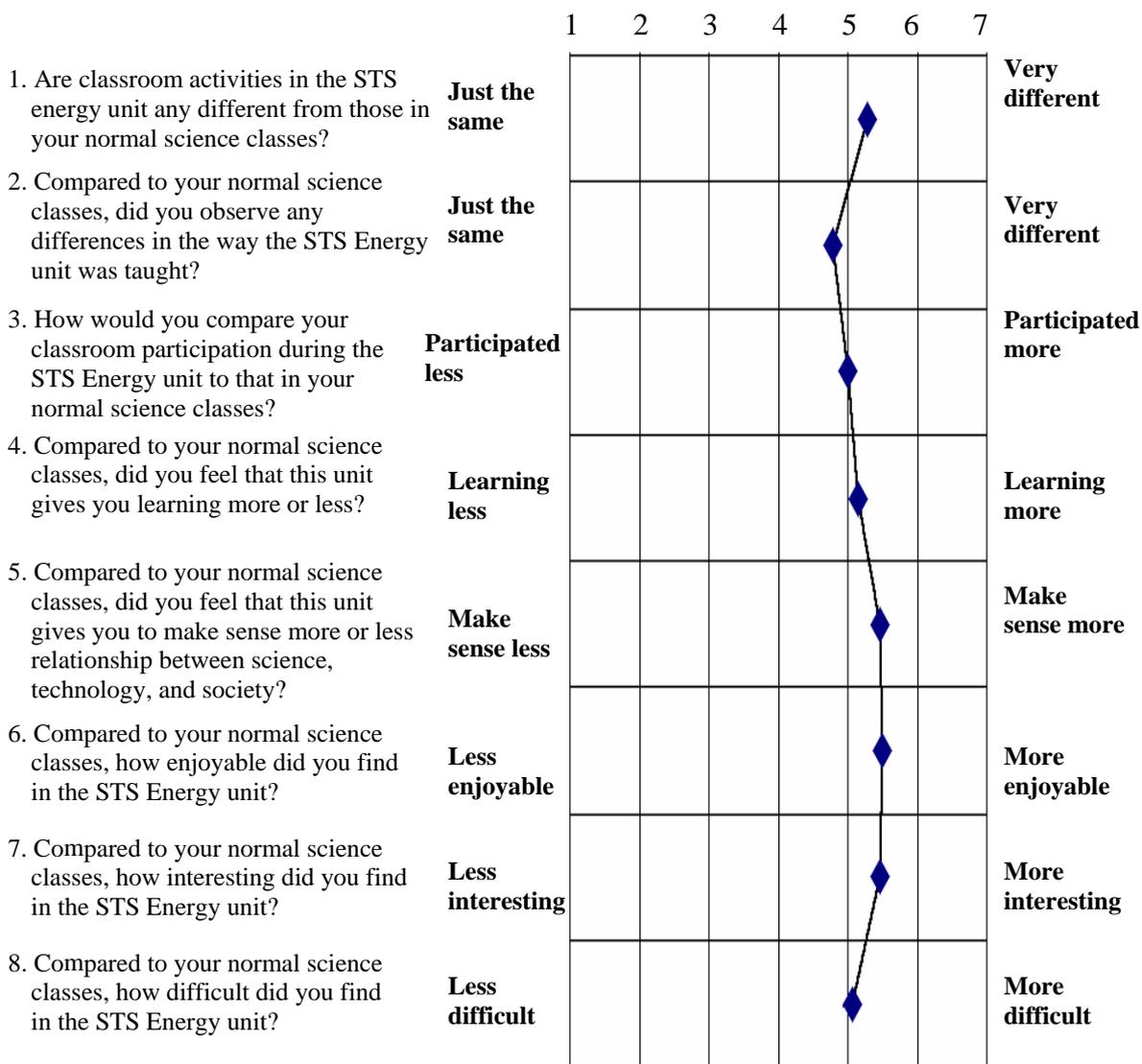


Figure 6.15 the SSRE Mean Rating School D Students to Comparison of the STS Energy Unit and Other Science Units.

Numerical and statistical details are provided in Appendix B. School D students' responses of the SSRE gave to comment overview of sub-unit 1 showed in Figure 6.13; overview of sub-unit 2 showed in Figure 6.14; and comparing the STS energy unit to the other science units showed in Figure 6.15.

School D students held the positive attitude toward the STS energy unit. Figure 6.15 revealed that the school D students had positive attitude towards the overview of sub-unit 1. They thought that all the main activities of sub-unit 1 quite

were interesting. They felt that the activities for the solutions of the increased petrol price situation were the most interesting. Figure 6.14 revealed that school D students had positive attitude towards the overview of sub-unit 2. They felt that all the main activities of sub-unit 2 were quite interesting. They thought that the most interesting the main activity was the Nam-pong power plant trip.

When the unit was compared to the other science unit, students felt that the STS energy unit has motivation more. Figure 6.15 revealed that the school D students had more positive attitude towards the STS energy unit than the other units that they had covered in science. They felt that classroom activities and the way what they were taught were different. They enjoyed and participated more in the STS energy classroom. They thought that the STS energy unit gave them more learning and making sense of relationship between science, technology, and society. However, it seemed that they felt that the STS energy unit was more quite difficult than their normal science units.

3.3 Teacher school D reflection

The meeting after the intervention allowed Pim to reflect her ideas about students' learning. Pim commented both the strength and some difficulties of her STS energy teaching and learning. Each aspect is discussed below.

3.3.1 The Strengths of the STS Energy Teaching and Learning

The strengths involved enhancing students' thinking skills, and motivation. This unit has given students chance to develop their thinking skills. Pim observed that her students were not confident to express their ideas. They worried about right or wrong ideas because they never were given a chance to express their ideas. This unit was quite different as Pim stated:

Students never practiced their thinking skills before this unit. Normally, they usually find all the knowledge that is provided in the reading sheet. The

worksheet is used only revise the knowledge that is previously mentioned in the reading sheet. This unit allowed them to give their ideas in the worksheet. Initially, they were afraid that their ideas would be wrong. I think they can think but they worry that it might be wrong.

There were many students to attend the classroom that it was unusual. Few students skipped the class which reflected how the unit motivated students. Pim thought that students were motivated with giving more participation. School D students cannot keep concentration on lectures. They preferred to talk to each other rather than to follow their teacher lecture. As Pim commented:

... Normally, there are a number of students to skip the class particularly the boys. I was very worried that students would be bored during two hours of science class. Today, this unit is different. They participate more. They might forget how much time going because they talk to each other all the time. If teacher lecture, students will yawn, be absent minded and boring, and seem to focus on the other thing.

Motivation is confirmed with considering Na's case that she was lack of reading skill and usually skipped the class. Na tried to analyze the Mae moh situation to provide the role-play. She paid more attention comparing to her first semester studying as Pim commented:

... Na, she usually skipped the class in the first semester. She cannot read fluently. I have seen prepare for the role-play of the Mae moh for many days.

3.3.1 Some difficulties of the STS Energy Teaching and Learning

There were some difficulties for school D teaching and learning. These include language, thinking, and reading skills. The northeastern dialect seemed to be obstacle for the school D students. They lost their confident for discussion because they could not speak well the standard Thai language. As Pim stated:

Some students did not dare to talk. They were shy to talk but they can write their ideas. They are afraid that they might miss the standard Thai language, and then their friends will butt in their northeastern dialect. I always cheer them up to speak the standard Thai language in the classroom.

Students' thinking is another difficulty of the school D students. Number of students needs to develop their thinking skills. As mentioned earlier, they never practiced their thinking skills. Pim perceived that the STS energy teaching and learning needed students' higher order thinking as she commented:

... I think that my students seem to have trouble for solving problem and find alternative solution. The most students could not give their ideas. I think that it is higher order thinking.

Reading skills are also difficulty of the school D students' learning in the STS energy unit. Social issues require students to reading for analyze the situation and find alternative solution. But, number of students cannot read to make a summary for the situation of social issues. As Pim commented:

...They have some problems of reading. The most students could not make a summary what they are reading. Some students could not fluency read. Therefore, I have mix students' ability for a group to balance the classroom.

4. Reflection from the Three Schools Further Trialing the STS Energy Unit

This part is an analysis across the three cases of the further trialing. Teachers and students' responses to the STS energy unit between three schools are compared and contrasted to provide a holistic view of the further trialing. The findings indicated that the STS energy unit could be well applied in three different schools. The STS energy teaching fostered students across three schools to gain not only energy concepts but also thinking skills classifications, and decision making about

energy related technological and societal issues. Additionally, they had positive attitude towards the STS energy unit. Each aspect is discussed below.

4.1 Three Schools Students' Understanding of Energy Concepts

Students' understanding of energy concepts is one of aspects that could reflect how enhancing the STS energy teaching and learning works. The development of school B, C, and D students' understanding of energy concepts are compared and contrasted. These energy concepts include students' understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. Each aspect is discussed below.

Students across three schools developed their understanding of energy forms and sources. Majority of students across three schools could give the mains of energy forms given from battery (see Table B3.1); recognize the definition of kinetic and nuclear energy (see Table B3.2); and identify sources of renewable energy and its forms (see Table B3.6). However, it seemed that students across three schools had difficulty to clarify forms of potential energy. There were not a number of students across three schools to be able to identify gravitational and chemical potential energy (see Table B3.4 and B3.5). These might cause from their missing key idea of potential energy. Potential or possible doing work was expected to be understood as a key idea of potential energy but there were a few students across three schools to perceive this idea that showed in Table B3.11.

Students' discussion in classroom revealed that students could describe energy transformation as step by step. However, in order to give the best explanation of energy transformation, students need to recognize some waste energy when they described energy transformation. It seemed that the most school D students would recognize the waste energy spreading. The majority of school D students could give the best explanation of energy transformation in a television and coal generating power that energy spreading needed to be identified; but there were not a number of school B and C students (see Table B3.14 and Table B3.24). Additionally, it seemed

that student missing key idea of potential energy influenced description of energy transformation. There were not a number of students across three schools to be able to select the best explanation of energy transformation resulting from the hydro generating power (see Table 3.23). They identified the water energy instead of the gravitational potential energy.

Classroom observation revealed that all the participating teachers have clarified the concept of the law of energy conservation but they did not identify the term. This reflected that their teaching has elaborated from the former grade 9 textbooks that generally, clarified the concept of the law of energy conservation but it did not identify the term. This would affect students' understanding. There were not a number of students across three schools to be able identify the term of the law of energy conservation. These include selecting the two situations that represent the concept of the law of energy conservation (see Table B3.16); and identifying the statement of the law of energy conservation (see Table B3.17). Although there were not many students across three schools who stated the law of energy conservation, they would make sense the concept. However, students, who could not state the law of energy conservation, would make sense the concept because they understood the concept of energy transformation.

Energy test indicated that students across three schools gained their understanding of energy degradation. Majority of students across three schools recognized energy spreading in the use energy of electrical devices (see Table B3.14), and asking the problem of never turn all the energy for use (see Table B3.29). Interestingly, the majority of students across three schools gave reason of "energy can be transformed into non-useful forms of energy (e.g. waste heat) for energy saving (see Table B3.12). However, their descriptions of energy transformation, sometime, were neglected the waste energy particularly clarifying a long step of energy transformation. Only majority of school C and D students could select the description of energy transformation resulting from a hydro and coal generating power which contained the heat spreading out; respectively (see Table B3.23 and Table B3.24).

Above discussion indicated that the school B, C, and D students developed their understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. However, there were more amounts of school B and C students who gave correct answers in the energy test in each item except items involving energy degradation than school D students. The concept of energy degradation did not appear in the general Thai Grade 9 science textbook. This suggests that students' tuition in the institute outside schools may influence their understanding of energy concepts. Students in the city and towns were more pressured from value education as memorizing knowledge for taking examinations than schools in the rural areas (Kaewdaeng, 2003). They usually spend time after normal school time in tuition institutes to help students memorize knowledge.

4.2 Three Schools Students' Thinking Skills

The STS energy unit gave students chance to make skeptical ideas to the energy issues related technological and societal aspects. Students' posing questions could be viewed their thinking skills classifications. The number of posed questions in the Identification of social issues stage was counted and categorized each question by its orientation. The three question orientation attributes include phenomenon or problem description, hazards related to the problem, and treatment or solution. Zohar and Dori (2003) suggested that proposing questions in orientation of solution would be viewed as a higher level of understanding the problem than describing it, and finding treatment or solution was more positive and productive than just identifying hazards.

The data interpretation revealed that the majority of school B students posed the hazard oriented questions but the majority of school C and D students posed the phenomena oriented questions. This assumes that the majority of school B students had a higher level of thinking skills classification. It seemed that the school B students would have more chance to practice their thinking than others before the STS energy unit. However, the trend of posing the questions indicated that students

have developed their thinking skills classification. School C and D students seemed to decrease the phenomenon oriented questions, and to increase the hazard and solution oriented questions comparing sub-unit 1 to sub-unit 2 (See the Figure 4.5 and the Figure 4.10). Although the school B students had posed a high percent of the solution oriented questions both in sub-unit 1 and 2, they also had decreased the phenomenon oriented questions, and to increase the hazard and solution oriented questions comparing sub-unit 1 to sub-unit 2 as showed in the Figure 4.1.

Students across three schools gained more seeking practical solution to a given problem rather than being fixated on requiring about risks. Increasing the hazard and solution oriented questions indicated that the STS energy unit continually supported the development of their thinking skill classification from sub-unit one to sub-unit two. Interestingly, there was a huge increase of solution oriented question for school C and D students. This assumed that they expanded higher level of thinking skills classification. This reflected also that number of them had lower level of thinking skills before the STS energy unit. Therefore, the STS unit could enhance students to develop their thinking skills although they had different backgrounds and prior knowledge.

4.3 Three Schools Students' Decision Making about Energy Related Technological and Societal Issues

The STS energy unit raised students the energy issues that required decisions making. Students had chances to gain their understanding of what, why, and how ideas of application scientific and other knowledge worked through the process of decision making. Their decision making was not only developed based on scientific knowledge but also based on their value judgments that were made based on societal, economical, and environmental aspects. As a process of decision making, students across three schools normative decision making could be viewed including identifying possible way, developing criteria for decision making, validity and clarification of information, selecting an alternative and reviewing the possible

improvement. Students' decision making for the issues of the increased petrol price and the Mae moh situation are clarified below.

4.3.1 Three schools students' Decision Making for the Issue of the Increased Petrol Price

Sub-unit one allowed students to make decision on alternative actions for the situation of the increased petrol price. Students' process of decision making elaborated them to their value judgments concerning with scientific knowledge, economical aspects, helping society, environment concerns, people behavior, and the use of local materials. This could be viewed as the overview of the three schools students' process of decision making that would be clarified as below.

School B students began their decision making process with listing the possible alternative ways of action. These include organizing project of electric energy and petrol saving, the alternative energy sources (e.g. bio diesel, gasohol, bio gas, biomass, and solar power). Then, they clarified information for alternative ways of action. Their clarifications could be divided into two aspects including reviewing literature about scientific knowledge and doing experimentations. Students' literature review involved petrol saving strategies, and knowledge of alternative energy. For example, Kaew's group clarified the strategies of petrol saving; and Phan's group did biogas experiments. Their possible ways of action were evaluated concerning with economical aspects, helping society, and local materials use. For example, students considered the farmers' income when the cassava as local material was used to produce ethanol for gasohol. Gaining profit from the leaving materials was also considered by school B students. For example, Phan's group decided to do experiment on biogas because they appreciated the left-over in the restaurants and the temples. Additionally, it seemed that school B students considered multidimensional aspects for solving problems. For example, Kaew's group evaluated their campaign of petrol saving concerning with the traffic jam of the main road in the city of Khon Kaen and cost of a car using petrol.

School C students listed possible alternative ways of action for this issue involving organizing project of petrol and electric energy saving. They focused on various samples including people in the town transport centre, the market, and their villages. Considering the sample suggested them find the ways of taking actions. Their information clarifications for alternatives could be divided into two aspects including review literature about scientific knowledge and survey of preliminary information. Students' literature review include the origin of petrol, the limitation and advantages of petrol, the energy saving strategies of other organizations, and amount use of non-renewable energy sources in Thailand. Students' survey for preliminary information include Caths' group survey of people opinion about petrol saving, and Dear's group survey of the peak of electric energy use a day in their village. Their survey allowed them to obtain the strategies of energy saving that would be appropriate with their communities. For example, Dear's group created the Ten Rules of electric energy saving for the rice mills in their village. Their ideas concerned with the rice mill management, technique to mill the rice, and people behaviors. However, Dear's group ideas were validated by the mill owners. This gave them to concern more the economical aspects as they stated "... this is the business matter. The rice mill owners have to compete against each other for gaining more profit ...". This assumed that the process of decision making allowed them to evaluate their possible ways of action concerning with people opinion, and economical aspects. Additionally, environmental concerns and country development were also raised, for example, Pron's group concluded the advantages of petrol saving including "... government has money for the country development, carbon dioxide resulting from a car is decreased ...".

School D students listed possible alternative ways of action for the issue of the increased petrol price involving organizing project of energy saving, renewable energy sources. Then, they clarified information that could be divided into two aspects including what they were supposed to do and review the related knowledge. Their evaluation for the possible alternative ways of action concerned with people behavior. For example, Dol's group raised tactical strategies of energy saving campaign involving students' value of the song listening. They planed to

organize the school radio song program with inserting strategies of energy saving. The tactic of time was concerned for Pla's group. They believed that their persuasion about petrol saving would achieve if they allowed people to see the slogan board for a long period of time.

In conclusion, sub-unit one gave students chances to learn energy concepts and applied knowledge to society. Students applied knowledge of energy forms and sources, and other knowledge to help their society solving the problem of increased price of petrol. Mostly, they organized the project of energy saving and alternative energy sources. Process of their decision making reflected that their value clarification was different among three schools. Students from the city seem to concern more on the knowledge from textbooks than students from the rural area. This would be influenced from value of taking entrance examination to the well known schools and universities. School B students valued possible ways of action concerning with reviewing literature about scientific knowledge and doing experiments. School C students concerned with scientific knowledge, and people opinion. But, school D students concerned with people's behavior. Students' evaluation of way of actions reflected that they understood relationship between science, technology, and society. They evaluated possible ways for resolving the issues of increased petrol price concerning with economical aspects, helping society, country development, and using local materials.

4.3.2 Three schools students' Decision Making for the Issue of the Mae moh situation

Sub-unit two allowed students to make decision about alternative solutions for the Mae moh power plant where polluted the air. Students' process of decision making elaborated their value judgments concerning with scientific and technological knowledge, energy sources supply, electric energy supply, environment concerns, health, safety, electric energy saving and economical aspect. This could be viewed as the overview of the three schools students' process of decision making that would be clarified as below.

School B students considered whether the Mae moh power plant should be closed down or not. They clarified information possible alternatives including various kinds of the generation power, and the process of generating power. The Num-pong power plant trip allowed school B students to compare and contrast environment effects between the Num-pong and the Mae moh power plant. Students tried to detect pollution that would be generated by the power plant. They also clarified scientific knowledge about the generating power, for example, the close loop of boiling water, taking care of the generators, and distribution of electric energy. Their evaluation for the possible alternatives could be viewed during the role-play of the Mae moh situation. School B students raised the issues of moving the people away, moving the coal power plant away from the communities, and constructing new kinds of the power plant. Then, these issues were validated concerning with health of people, environment damages, electric energy supply, and cost of constructing a new power plant. Alternative energy sources e.g. solar power were raised to substitute coal. This assumed that their evaluation was made based on health, environment concerns, electric energy supply, and economic aspect.

School C students considered whether the Mae moh power plant should be closed down or not. They clarified information of possible alternatives. Each group of students tried to propose the type of power plant that they were interested in for substitution coal power plant that affected the environment. Various types of the power plants were proposed including storage water power plant, geothermal power plant, and nuclear power plant. The pumped storage power plant was proposed because they aware of water supply. The geothermal power plant was raised. Students thought that it did not affect the fresh air because they knew that the geothermal power plant was run in the resort, Chiangmai province, where they needed the fresh air. The nuclear power plant was also raised. However, their considering of the uranium supply and cost of constructing the nuclear power plant reminded them that it would be impossible for Thailand. The Num-pong power plant also was clarified. The Num-pong power plant trip allowed students to compare and contrast environment effects between the Num-pong and the Mae moh power plant. Students examined the Num-pong engineer's idea about the problem of sulfur dioxide, and the

alternative energy sources supply for the power plant. These indicated that their value clarification of various types of power plants concerned with energy sources supply, pollution, safety, and scientific and technological knowledge. Their evaluation for the possible alternatives could be viewed during the role-play of the Mae moh situation. Students evaluated the advantages to keep running the Mae moh power plant concerning with the electric energy supply for the wide area use. They worried about the industrial use of energy that would affect to the Thailand economic. They believed that the air pollution problem could be reduced.

School D students considered whether the Mae moh power plant should be closed down or not. They clarified information possible alternatives including various kinds of the generation power, and the process of generating power. The Num-pong power plant trip allowed them to discuss the scientific knowledge about the process of the thermal generating power and to provide information for the Mae moh situation. Students' discussion to the Num-pong power plant engineers focused on technical process of the generating power, budget, alternative energy sources, and environment concerns. Technical process of generating power was clarified. For example, students wondered how the steam could generate power, compared fuels generating power, and considered alternative energy sources use in case of the natural gas and diesel running out. Students' clarification revealed their environment concerns. For example, they focused on the high temperature emitted air that could be affected the environment. Their evaluation for the possible alternatives could be viewed during the role-play of the Mae moh situation. Their evaluation was made based on safety and health, environment concerns, electric energy supply, electric energy saving, and the economic aspect. People safety and health were raised as the most important criteria for solving this problem. This could be viewed as presenting their three proposals for the alternatives. These proposals were made based on people's health concerns as following.

...First, move away the power plant. Second, keep running the power plant with no pollution. Third, if the power plant still be here, government has to give

people money to medicine all year long their sick as much as they need until they recover...

Environment concerns were also applied for evaluating possible alternatives. Students were aware of decreasing pollution. They proposed possible actions to decrease pollution problems. Finding alternative energy sources, no pollution effects, were considered. Students tried to identify energy sources that give no pollution. Available sources and its price were evaluated for possible alternatives. Additionally, the electric energy saving was raised in order to decrease the air pollution.

In conclusion, sub-unit two gave students chances to learn energy concepts and applied knowledge to society. Students applied knowledge of energy transformation and degradation, the law of energy conservation, and other knowledge to help their society solving the problem of the Mae moh situation. The Num-pong power trip allowed students across three schools to lively inquire scientific knowledge about generating power to apply for the Mae moh situation. For example, they probed engineers about close loop of boiling water, how steam generates power, pollution problems, comparing fuels generating power, and so on. Students' evaluation of way of actions for the Mae moh situation during the role-play reflected that they understood relationship between science, technology, and society. They evaluated possible solutions concerning with multidimensional aspects. However, there were little different value clarifications between three schools. School B and D students seems to focus more on people's safety and health, and environment concerns. They raised the issues of moving the people away, moving the coal power plant away from the communities, and constructing new kinds of the power plant which had no pollution. But, school C students strongly concerned aspect of country development. They perceived that the Mae moh power plant distributed electric energy wide areas. Closing down the Mae moh power plant would affect the industrial use of energy and Thailand's economic. The air pollution from the power plant could be reduced.

4.4 The Reaction to the Unit

The three school teachers and students reaction to the unit could be clarified into aspects. These include the strength and some difficulties of the STS energy teaching and learning. Each aspect is discussed below.

4.4.1 The Strengths of the STS Energy Unit

The strengths involve the motivation of the unit and enhancing students' quality of learning. Students' quality of learning includes enhancing students' thinking skills, students' giving ideas, investigation of scientific knowledge, and social responsibility. Each aspect is discussed as following.

The STS energy unit was motivating. Motivation could be viewed as the students' responses of the SSRE and teachers' reaction to the unit. The SSRE revealed that students across three schools had the positive attitude toward the STS energy unit. They thought that all the main activities of sub-unit 1 and 2 were quite interesting. School B and C students thought that the activity of studying of sources of renewable energy was the most interesting for sub-unit 1. But, School D students felt that the activities for solutions of the increased petrol price situation were the most interesting for sub-unit 1. Interestingly, students across three schools thought that the most interesting activity of sub-unit 2 was the Num-pong power plant trip. When the unit was compared to the other science unit, students across three schools felt that the STS energy unit has motivation more. They more enjoyed, participated, and made sense of relationship between science, technology, and society in the STS energy classroom. Additionally, Teacher Pim highlighted how her students were motivated by the STS energy unit. She clarified that normally, a number of her students usually skipped the class but there were many students to attend the STS energy unit. Pim thought that students were motivated with giving more participation. School D students cannot keep concentration on lectures. They preferred to talk to each other rather than to follow their teacher's lecture.

Three participating teachers thought that the STS energy unit enhanced students' thinking skills, students' giving ideas, investigation of scientific knowledge, and social responsibility. They appreciated the development of their students' thinking skills classification. Kunya felt that students had fun to study scientific knowledge because they had chances to express their ideas. She thought that the unit gave students chances to learn energy from various sources of knowledge and allowed students to investigate scientific knowledge. Ann thought that the unit gave students more chance to give ideas, investigate scientific knowledge, and social responsibility. Students gained confidence to express their ideas. Pim also observed that her students gained more confidence because they had more chance to express their ideas.

4.4.2 Some Difficulties of the STS Energy Unit

Three schools further trialing suggested some difficulties of the STS energy teaching and learning. These include teacher role, requiring students' responsibility, high classification of thinking, and Thai language skills. Each aspect is clarified as below.

The STS energy unit required teachers who could enhance students to study scientific knowledge through finding solutions of the energy issues related technological and societal aspects. Further trialing revealed that the STS energy unit lost Teacher Kunya's enhancing students to study energy concept. This obviously appeared in her teaching of sub-unit two. She lacked elaboration of several kinds of the power plant, the concept of energy transformation and degradation in the power plant. Her reflection to the unit confirmed how she perceived this unit. She perceived that the unit should give students more chance to study by themselves. She wished to foster students to find the solutions of social issues from various learning sources, and to take more participation in classroom but missed to focus students on energy concepts.

School C and D students reflected that some students had difficulty to learn in the STS energy unit. Teacher Ann thought that the STS energy teaching and learning could not work with some school C students who had no responsibility to investigate scientific knowledge and do some activities for their society. Teacher Pim reflected that there were some difficulties for school D students. Teacher Pim perceived that the STS energy learning required students' higher order thinking skills. She commented that her students never practiced their thinking skills, therefore; at the beginning it was very difficult to foster students to make skeptical ideas or think of any alternative solutions. Additionally, Thai language skills also are problems of school D students. Many of them could not read Thai fluently. They had difficulty to read for making a summary for the situation of the social issues. The northeastern dialect could be also considered. Some school D students lost their confidence for discussion because they could not speak well standard Thai language.

CHAPTER VII

CONCLUSIONS AND IMPLICATIONS

This chapter outlines the research objectives and methodology, and brings together the findings from the three phases of this study and examines how these findings inform the research questions. The chapter also outlines some implications of these findings for further research. Each aspect is clarified as below.

Overview of the Research Objectives and Methodology

This section presents the research objectives and questions, and then clarifies the research methodology. Each aspect is clarified below.

1. Research Objectives

This research presents enhancing of energy teaching and learning through STS approach in Khon Kaen province, Thailand. To achieve this aim, the research questions addressed are specified as following questions.

Question 1: What are students' existing ideas about energy and energy related technological and societal issues; and how do their existing ideas inform basis ideas for developing the STS energy unit?

Question 2: What are the participating teachers' existing ideas about energy and energy teaching and learning; and how do their ideas inform basis ideas for developing the program for enhancing the STS energy teaching?

Question 3: How do students respond to teaching trial intervention of the STS energy unit; and what information resulting from intervention could be applied to enhance the STS energy teaching?

Question 4: How does the researcher provide the participating teachers to teach energy through STS approach?

Question 5: What are the affective and cognitive outcomes, difficulties, and strengths for energy teaching through STS approach in the different three schools?

2. Research Methodology

This research was carried out with the 172 Grade 9 students in four different schools of Khon Kaen province, Thailand including school A, B, C, and D. The school A is located in a university in Khon Kaen province. School B is located in the city of Khon Kaen. School C is located in a small town of the Khon Kaen province at approximately 40 kilometres from the city of Khon Kaen. School D is located in a rural area of Khon Kaen province at approximately 60 kilometres from the city of Khon Kaen.

The research was designed in three phases under paradigm of interpretive research. These three phases include exploration, intervention, and evaluation phase. Each phase is outlined as following.

The first phase, the exploration phase, explored what students' ideas about energy concepts and energy related technological and societal issues, and what teachers' existing ideas of energy concepts, and perception of energy teaching and learning. The questionnaires were used for exploring students' and teachers' ideas. These questionnaires include (1) the Questionnaire of Student Energy Conception (QSEC); (2) the Questionnaire for Students' idea about Energy related Technological and Societal issues (QSETS); and (3) Questionnaire for Teacher Energy Perception (QTEP). The QSEC and QSETS were completed by school A, B, C, and D students. And, the QTEP was completed by school B, C, and D teachers. Then, the given ideas from these questionnaires were categorized. Each category of given ideas was discussed to develop assumption for developing the STS energy unit and the program of enhancing the STS energy teaching.

The second phase, the intervention phase, was the initial trialing the STS energy unit by the researcher in school A. The initial STS energy unit was developed based on assumption from the four schools students' existing ideas. The results of the initial trialing were monitored with the different instruments including participant observation, the energy test, document analysis, and informal conversational interview. Then, the information from these instruments was discussed for giving the implications for further trialing of the evaluation phase.

The third phase, the evaluation phase, aimed to evaluate how the unit works through enhancing the STS energy teaching and learning. The further trialing of the STS energy unit was carried out in three different schools including school B, C, and D. Before the further trialing, the teacher participants had to attend the program of enhancing the STS energy teaching. The working in schools, teachers and students' reflections was illustrated how the STS energy unit worked. Students' reflection includes the students' understanding of energy concepts, students' thinking and decision making skills, and students' reaction to the unit. Teachers' reflection includes an understanding of the STS approach and energy concepts, and teachers' reaction to the unit. Instruments were employed to give these reflections including participant observation, document analysis, energy test, semantic differential scale of students' reaction in energy unit (SSRE), and an informal conversational interview. Then, each school reflection was discussed, and then compared and contrast the reflection among three schools.

Research Findings

This research clarified the enhancing energy teaching and learning through the STS approach in Thailand. As the process of interpretation of enhancing teaching and learning energy through STS approach, the research was designed in three phases including exploration, intervention, and evaluation phase. Findings of each phase are outlined below.

1. Exploration Phase

This phase focuses on the following research questions:

What are students' existing ideas about energy and energy related technological and societal issues; and how do their existing ideas inform basis ideas for developing the STS energy unit? And, what are the participating teachers' existing ideas about energy and energy teaching and learning; and how do their ideas inform basis ideas for developing the program for enhancing the STS energy teaching?

Chapter 4 reported what students' ideas about energy concepts and energy related technological and societal issues, and what teachers' existing ideas of energy concepts and perception of energy teaching and learning. Students' existing ideas were used to develop the initial STS energy unit in the intervention phase. Teachers' existing ideas provided the program of enhancing the STS energy teaching. Each aspect is summarized as below.

1.1 Students' Ideas about Energy Concepts and Energy Related Technological and Societal Issues

The study revealed students' ideas about energy concepts, and students' ideas about energy related technological and societal issues in following conclusions.

Students' energy ideas about energy concepts were explored including students' existing ideas of energy formation, the law of energy conservation, energy transformation and degradation. The findings revealed that fundamental students framework of energy concept involved natural occurrence of energy things and living things; energy saving and appreciation of the value of energy; and perceiving energy through sources of energy. The well known forms of energy among school A, B, C, and D students include electric, heat, light and

mechanical energy. However, they confused between forms and sources of energy. Water was popularly recognized as energy form among school A and school B students. School C students were mainly confused by fuel as energy form. Students' ideas about the law of energy conservation, the findings revealed that students' giving description the term involved saving of energy sources, storing up energy, and worthy energy use. These reflect that student experiences might affect scientific concepts because term of conserving (in Thai 'A-nu-rak') is also used in everyday language. 'A-nu-rak' is viewed as preserving, storing up or saving. Students across four schools seemed to only understand ideal concept of energy transformation. Their giving description of energy transformation mostly considered only changing of one energy from to another obvious useful or observable form of energy. The findings revealed that students across four schools held slightly existing ideas about energy degradation. They gave some ideas about the nature of energy including energy spreading and difficulties of reusing energy.

Students' ideas about energy related technological and societal issues were discussed into three aspects. Firstly, students' ideas about technological and societal aspects influences on the study of energy, the findings revealed that students across four schools took the country development into account for decision making of need to study energy. They perceived that their country needed to be more development. Secondly, students' ideas about energy influenced on issues related technological and societal aspects, the findings revealed that students across four schools held strongly belief of scientific endeavor. Issue of country development supports them to use scientific knowledge resolving social. New innovation of energy could be used for solving social problems of the use of energy. Based on their strong belief in scientific knowledge, they preferred to respect decision of people who have better understanding of energy for decision making of use of energy. Their ideas seem to be general Thai because Thai are aware of authority. Children are usually taught that good children must obey parents, teachers and adults who have better understanding (Titthummo, 2004). Finally, students' values influences on energy

consumption, the findings revealed that students usually concern with issues of country development. Their values were based on concerning with increasingly use energy in the future because of industrial country. Therefore, students' ideas of energy saving were established because of concerning with storing up energy for the future use. This reflects that environment setting, beliefs, society, and culture situate them into distinguish normative decision making ideas.

Above findings suggested interesting assumptions for the developing the STS energy unit. Regarding the students' existing ideas, the unit should be started with sources of energy, natural occurrence of energy in things and living things, and issues of energy saving; placed the electric energy and sun as core content. The unit should give students chances to distinguish between energy sources and forms; and enhance student description of energy transformation to concern with converting to several forms of energy, and the relationship between the law of energy conservation, energy transformation and degradation. The unit also proposed activities of decision making between energy use, public concern, and other constraints; and enhance student perception of social aspects. These assumptions were employed for developing the STS energy that was illustrated in Chapter 5.

1.2 Teachers' Existing Ideas of Energy Concepts and Perception of Energy Teaching and Learning

This section outlined school B, C, and D teachers' existing ideas of energy concepts and perception of energy teaching and learning. Then, the section discussed how teachers' existing ideas informed basic ideas to develop the program for enhancing the STS energy teaching. Each aspect is clarified below.

Participating teachers' existing ideas about energy forms, the law of energy conservation, energy transformation and degradation were explored. Findings revealed that teachers held the framework description of energy concept as energy sources and forms of energy. This was consistent with students'

existing ideas. Teachers' existing ideas about the law of energy conservation could be seen as two ideas including energy conserving or saving, and idea of energy transformation. Teachers' existing ideas about energy transformation appeared in both the framework description of the one step of energy transformation and the multi-step. Ann held the framework description of the one step of energy transformation. Kunya and Pim held the framework description of the multi-step of energy transformation. Teachers' existing ideas about energy degradation, the findings revealed that giving description of energy transformation concerning with the usefulness of energy to decline. Additionally, given ideas of difficulties of generating power and origin of sources suggest that teachers concern with the concept that energy was hard to reverse to become more useful energy. These two ideas indicate that teachers hold some ideas of energy degradation.

The findings of participating teachers' perception of energy teaching and learning revealed that they concerned with three aspects. First, teachers concerned with energy teaching and learning for application energy concepts in everyday life. Second, teachers believed that energy teaching should engage in students' experiences. Third, teachers wanted to manage instruction that empower students to be able to think, act, and solve problems of energy concept by themselves.

Finally, the program of enhancing the STS energy teaching was provided regarding participating teachers' existing ideas about energy and perception of energy teaching and learning. The findings of teachers' existing ideas about energy concepts indicated that the participating teachers slightly understood energy concepts. Their perception of energy teaching and learning regarded empowering students to be able to think, act, and solve problems; and application of energy concepts related to student everyday experiences. It seemed to be difficult for participating teachers to blend content of energy and pedagogy for enhancing student understanding of energy and application of energy. To enhance teachers to develop student understanding of energy concept, decision making,

and taking action for resolving societal issues related energy and technological aspects. Therefore, they should be provided with the workshop of learning theories and the STS approach. The program of enhancing the STS energy teaching should also enter the illustration of the energy concepts. These assumptions were applied for enhancing the STS energy teaching and learning in three different schools, Khon Kaen province that could be seen in the Chapter 6.

2. Intervention Phase

This phase focuses on the following research questions:

How do students respond to teaching trial intervention of the STS energy unit; and what information resulting from intervention could be applied to enhance the STS energy teaching?

Chapter 5 reported research outcomes of the intervention phase. The intervention phase involves the developing the initial STS energy unit and then trialing this unit by the researcher in school A. The initial trialing aimed to find some suggestions for enhancing the STS energy teaching in three different schools. This section outlined the designing the initial STS energy unit. Then, the section discussed the outcomes of the initial STS energy intervention to give implications for enhancing the STS energy teaching in the evaluation phase. Each aspect is highlighted below.

2.1 Summary of Developing the Initial STS Energy Unit

Developing the STS energy unit aimed to allow students' energy learning through identifying problems with local interest and impact about energy related technological and societal issues, and then solving these issues. The unit, therefore, was developed based on assumptions regarding students' existing ideas about energy, and energy related technological and societal issues. In order to enter the relationship between science, technology, and society into the energy

class, the STS energy unit was developed through five stages. These included an identification of social issues, identification of potential solutions, need for knowledge, decision-making, and socialization stage. The initial STS energy unit consists of three sub-units. The classroom activities were summarized in Table 5.1.

2.2 Outcomes of the Initial STS Energy Unit

The initial STS energy unit was trialed by the researcher in the school A. This initial trialing aimed to find some suggestions for enhancing the STS energy teaching in three different schools. The outcomes revealed that the initial STS energy unit not only enhanced students' understanding of energy concept but also gave school A students chances to develop their thinking skills classification, and decision making about energy related technological and societal issues and gaining affectiveness to the energy unit. Each aspect is summarized below.

The development of students' understanding of energy concepts includes energy forms, energy transformation and degradation, and the law of energy conservation. The energy test revealed that approximately fifty percent of students could identify forms of energy resulting from the energy sources although a number of students were confused between forms and sources of energy during doing worksheet. The students' worksheet indicated that the majority of students held framework of multi-step to describe energy transformation resulting from using electric devices and the process of generating power. Students' ideas about tracing back energy forms resulting from using a car and an iron revealed that there were quite a number of students who could trace back far to origin of energy sources and far to the sun. These suggested that they did not only recognize ideal concept of energy transformation but also converting to several forms of energy. Students' framework of multi-step also indicated that they consider energy degradation. Students' worksheet revealed that approximately thirty percents of students concerned with heat energy or waste heat spreading out for describing energy transformation in electric devices and the

process of generating power. Additionally, it seemed that students' gaining understanding of energy transformation and degradation supported their understanding of the law of energy conservation. The energy test showed that approximately fifty percent of students correctly gave its' definition.

The initial STS energy unit also enhanced students to generate their process of decision making. As a process of decision making, themes of school A students normative decision model could be viewed including identifying possible way, developing criteria for decision making, validity and clarification of information, and choosing an alternative. Their process of decision making for those issues were not only developed based on scientific knowledge but also on their value judgments that were made based on the societal, economical, and environmental aspects. For example, students thought that Thailand should use alternative energy for protecting the side effect of oil embargo because they concerned with cheaper budget of the local materials and helping farmer to gain more profit (e.g. using the gasohol). Students began solving the situation of the Mae moh power plant that polluted the air by listing other types of power plant. Hydro, solar and wind power were considered because they safe for environment and people living. However, they were aware of the high cost of constructing a solar power plant as well.

The initial unit enhanced students to develop their thinking skills classifications. This could be seen when they expressed their complexity of questions and statements that involved application, analysis, value judgment, and expression of an opinion regarding controversial issues.

Students' reaction to the unit revealed that they had effectiveness to the unit. Students were interested in activities of the unit because it fosters their analysis thinking, learning about unexpected knowledge, and fun of some discussion issues.

2.3 Suggestions from the Initial STS Energy Unit

According to the outcomes of initial trialing, it illustrated the strengths of the energy teaching and learning through STS approach. Students not only gained their understanding of energy concept but also developed their thinking skills classification, and decision making. These results had some implications for enhancing the STS energy teaching and learning. These include the following aspects. The STS energy teaching and learning should remind that students would take time to cope with each social issue. To manage science teaching, teachers may integrate more concepts into the initial STS energy unit. Paying too much attention on social issues might affect the development of students' understanding of energy concepts. The STS energy intervention, therefore, should be keep balance students' energy concepts and social issues. In order to foster students to concern with various aspects, teachers would guide them to evaluate the advantages and disadvantages of the possible solutions or ways of actions. It was found that students' thinking showed some unexpected opinion and value clarifications. Teachers should give more chance all the students to express their thinking in order to reach suggest the multidimensional aspects of possible way of actions. In order to enhance students to understand energy concepts, students should be reminded to clarify the relationship of energy transformation and degradation, and the law of energy transformation. The finding about students' understanding of energy concepts could be assumed that this relationship supported their understanding of the law of energy conservation. Identifying energy forms should be emphasized. The initial trialing revealed that students' mistakes of identifying energy forms affect their description of energy transformation. Teachers should be reminded that energy degradation should not be ignored because energy spreading supported students to consider other forms of energy which were not obviously observable in energy transformation; and well understand the law of energy conservation.

3. Evaluation Phase

This phase focuses on the following research questions:

How does the researcher provide the participating teachers to teach energy through STS approach?

What are the affective and cognitive outcomes, difficulties, and strengths for energy teaching through STS approach in three different schools?

Chapter 6 reported research outcomes of the evaluation phase. Evaluation phase aimed to enhance energy teaching and learning through STS approach in three different schools in Khon Kaen province, Thailand, including school B (located in the city), school C (located in the small town), and school D (located in the rural area). This section outlined the program for enhancing the STS energy teaching, and participating teachers and students' reflection to the STS energy unit. Each aspect is discussed below.

3.1 Summary of Program for Enhancing STS Energy Teaching

This program was provided based on the existing participating teachers' ideas about energy concept and energy teaching and learning. The Questionnaire for Teacher Energy Perception (QTEP) and interviews gave information of teachers' ideas existing that were detailed in chapter 4. Teacher existing ideas indicated that they should be trained to develop their understanding of energy concepts and application of energy. The program provided full-day workshops followed by trialing in classrooms (See Figure 6.1 in Chapter 6). Three workshops were placed between classroom teachings in order to provide teachers with opportunities to build stronger foundations for enhancing their teaching. The first workshop was provided to enhance teachers' existing ideas of energy concepts and energy teaching through STS approach. The second and third workshops aimed to reflect and refine teaching strategies concerning the STS approach.

3.2 Reflection of Enhancing the STS Energy Teaching and Learning

Teachers and students' reflection were collected and interpreted during the program for enhancing STS energy teaching. These reflections illustrated how the STS energy unit worked in three different schools. Students' outcomes reflected the strengths of the STS energy unit that it did not only enhance students' understanding of energy concepts but also students' thinking skills classification and decision making for energy issues related technological and societal aspects. But, a range of developing of their understanding and skills was different depending on their prior knowledge and context. Students' and teachers' reaction to the unit indicated that it could more motivate students than their normal class particularly giving more chance to talk to each other and learning activities outside classroom. However, there were some difficulties for energy learning through STS approach. These include requiring students' responsibility, high classification of thinking, and the Thai language skills to interpret information; and teacher's role for energy teaching and learning through STS approach. Each aspect is detailed as below.

3.2.1 Developing Students' understanding of Energy Concepts

The finding reflections revealed that school B, C, and D students had the development of understanding of energy sources and forms, energy transformation, the law of energy conservation, and energy degradation. However, there were more school B and C students who correctly completed the energy test in each item than school D students except items involving energy degradation. The concept of energy degradation did not appear in general Thai Grade 9 science textbooks. This suggests that students' tuition in the institute outside schools may influence their understanding of energy concepts. Students in the city and towns were more pressured with value education as memorized knowledge for taking examinations than schools in the rural areas (Kaewdaeng, 2003). They usually spend time after normal school time in tuition institutes to help students memorize knowledge.

3.2.2 Developing Students' Decision making

The STS energy unit raised students the energy issues that required decision making. Students had chances to gain their understanding of what, why, and how ideas of application scientific and other knowledge worked through the process of decision making. Their decision making was not only developed based on scientific knowledge but also their value judgments that were made based on societal, economical, and environmental aspects. As a process of decision making, students across three schools normative decision making could be viewed including identifying possible way, developing criteria for decision making, validity and clarification of information, selecting an alternative and review the possible improvement. Students' decision making for the issues of the increased petrol price and the Mae moh situation are summarized below.

Sub-unit one gave students chances to learn energy concepts and applied knowledge to society. Students applied knowledge of energy forms and sources, and other knowledge to help their society solving the problem of increased price of petrol. Mostly, they organized the project of energy saving and alternative energy sources. Process of their decision making reflected that their value clarification was different among three schools. Students from the city seem to concern more on the knowledge from textbooks than students from the rural area. This would be influenced from value of taking entrance examination to the well known schools and universities that was consist to Kaewdaeng's (2003) argument. School B students valued possible ways of action concerning with reviewing literature about scientific knowledge and doing experiments. School C students concerned with scientific knowledge, and people opinion. But, school D students concerned with people's behavior. Students' evaluation of way of actions reflected that they understood the relationship between science, technology, and society. They evaluated possible ways for resolving the issues of increased petrol price concerning with economical aspects, helping society, country development, and using local materials.

Sub-unit two gave students chances to learn energy concepts and applied knowledge to society. Students applied knowledge of energy transformation and degradation, the law of energy conservation, and other knowledge to help their society solving the problem of the Mae moh situation. The Num-pong power trip allowed students across three schools to lively inquire scientific knowledge about generating power to apply for the Mae moh situation. For example, they probed engineers about close loop of boiling water, how steam generates power, pollution problems, comparing fuels generating power, and so on. Students' evaluation of way of actions for the Mae moh situation during the role-play reflected that they understood the relationship between science, technology, and society. They evaluated possible solutions concerning with multidimensional aspects. However, there were little different value clarifications between three schools. School B and D students seem to focus more on people's safety and health, and environment concerns. They raised the issues of moving people away, moving the coal power plant away from the communities, and constructing new kinds of power plant which had no pollution. But, school C students strongly concerned about the aspect of country development. They perceived that the Mae moh power plant distributed electric energy for wide areas. Closing down the Mae moh power plant would affect the industrial use of energy and Thailand's economy. The air pollution from the power plant could be reduced.

3.2.3 Developing Students' Thinking skills Classification

The STS energy unit gave students chance to make skeptical ideas to the energy issues related technological and societal aspects. Students' posing questions could be viewed as their thinking skills classifications. Zohar and Dori (2003) suggested that the proposing question in orientation of solution would be viewed as a higher level of understanding the problem than describing it, and finding treatment or solution was more positive and productive than just identifying hazards. Comparing between sub-unit one and two revealed that students across three schools gained more seeking practical solution to a given

problem rather than being fixated on requiring about risks. Increasing the hazard and solution oriented questions indicated that the STS energy unit continually supported the development of their thinking skill classification from the sub-unit one to the sub-unit two. Interestingly, there was a huge of an increase solution oriented question for school C and D students. This assumed that they expanded a higher level of thinking skills classification. This reflected also that number of them had a lower level of thinking skills before the STS energy unit. Therefore, it assumes that the STS unit could enhance students to develop their thinking skills although they came from different background and prior knowledge.

3.2.4 Motivation of the STS Energy Unit

Motivation could be viewed as the students' responses of the SSRE and teachers' reaction to the unit. The SSRE revealed that students across three schools had the positive attitude toward the STS energy unit. When the unit was compared to the other science unit, students across three schools felt that the STS energy unit has motivation more. They more enjoyed, participated, and made sense of relationship between science, technology, and society in the STS energy classroom. Interestingly, Teacher Pim highlighted that school D students usually skipped because they could not keep concentration on lectures. But, there were many students to attend the STS energy unit. Pim thought that students were motivated with giving more participation. They preferred to talk to each other rather than to follow their teacher's lecture. Additionally, Kunya and Ann felt that school B and C students, respectively, had fun to study scientific knowledge because they had chances to express their ideas.

3.2.5 Some Difficulties of the STS Energy Teaching and Learning

Reflection from three schools revealed some difficulties of the STS energy teaching and learning. These include requiring students' responsibility, high classification of thinking, and Thai language skills to interpret information; and teacher's role for energy teaching and learning through STS

approach. Teacher Ann thought that the STS energy teaching and learning could not work with some school C students who had no responsibility to investigate scientific knowledge and do some activities for their society. Teacher Pim commented that school D students never practiced their thinking skills, therefore; at the beginning it was very difficult to foster them to make skeptical ideas or think of any alternative solutions. Additionally, many of them could not read Thai fluently that affected their information interpretation. The northeastern dialect could be also considered for school D students. They lost their confidence for discussion because they could not speak well standard Thai language. Finally, teacher's role, the STS energy unit required teachers who could enhance students to study scientific knowledge through finding solutions of the energy issues related technological and societal aspects.

Implications for Science Teaching and Learning

This study indicated the strengths of energy teaching and learning through the STS approach. The STS energy teaching and learning not only enhanced students' understanding of energy concepts but also gave students chances to develop their thinking skills, decision making about energy related technological and societal issues, and gaining affective learning. This study also reported the process of developing the STS energy unit, and the evaluation of the STS energy intervention in three different schools. Therefore, this research may have implications for science teaching and learning. These include the process of developing the STS unit, the STS energy teaching and learning with various students' abilities, and giving information for science education stakeholders to take further applications of other science concepts.

This research clarified the process of developing the STS energy unit that was suggested by students' existing ideas about energy. The given ideas from the QSEC and the QSETS were categorized. Each category of given ideas was discussed to develop assumption for developing the STS energy unit. Finally, the findings revealed that this unit allowed students across different school contexts to

gain their understanding of energy concepts from their existing ideas. This process may give suggestions for developing other science unit through the STS approach.

The evaluation phase suggested that the STS energy unit could be applied generally with Grade 9 students in Khon Kaen province. The findings revealed that the STS energy unit motivated students across three different schools. Obviously, many of school D students, who normally skipped the science class, came to class and discussed about energy issues. They preferred to talk to each other rather than to follow their teacher lecture. The findings showed also that students across three different schools were enhanced thinking skills classifications, process of decision making, giving ideas, investigation of scientific knowledge, and social responsibility.

The study reported the developing the STS energy unit and evaluated how the intervention worked in the different three schools. The strengths and some difficulties of the applying the STS energy unit also were clarified. The strengths involved enhancing students' quality of learning (i.e. energy concepts, thinking skills, and decision making), and the motivation of the unit. Some difficulties of the STS energy teaching and learning include appropriate teachers' roles; and requiring students' responsibility, high classification of thinking, and Thai language skills. These findings would give information the science education stakeholders in Thailand who may take further applications of science teaching through the STS approach.

REFERENCES

- Aikenhead, G. 1994a. What is STS Science Teaching? In Solomon, J. and Aikenhead, G. (Eds.), **STS Education: International Perspective on Reform**. New York, USA: Teachers College Press, Columbia University. 169 -186.
- Aikenhead, G. 1994b. Consequences to Learning Science Through STS: A research Perspective. In Solomon, J. and Aikenhead, G. (Eds.), **STS Education: International Perspective on Reform**. New York, USA: Teachers College Press, Columbia University. 169 -186.
- Aikenhead, G. S., Ryan, G.A., and Fleming, R.W. 1989. **Views on Science-Technology-Society: Form CDN.mc.5**. Available: <http://www.usask.ca/education/people/aikenhead/vosts.pdf>
- Aikenhead, G.S. and Otsuji, H. 2000. Japanese and Canadian Science Teachers' Views on Science and Culture. **Journal of Science Teacher Education**. 11(4): 277 – 299.
- Aikenhead, G.S. and Ryan, A. 1992. The development of a New Instrument: 'Views on Science – Technology – Society' (VOSTS). **Science Education**. 76(5): 447 – 491.
- Altheide, D. L. and Johnson, J. M. 1994. Criteria for assessing interpretive validity in qualitative research. In Denzin, N. K. and Lincoln, Y. S. (Eds.), **Handbook of qualitative research**. Thousand Oaks, California, USA: Sage Publication, 485 – 499.
- Asian Development Bank (ADB). 2002. **Teacher Development for Quality Learning: The Thailand Education Reform Project, March 2002**. Brisbane, Australia: Office of Commercial Services, Queensland University of Technology. Available: <http://www.worldedreform.com/pub/fulltext4.pdf>,

- Assessment Resource Banks (ARBs) 2003. **Science Bank**. Available:
<http://arb.nzcer.org.nz/nzcer3/searchs.htm>, October 20, 2003.
- Banister, P., Burman, E., Parker, I., Taylor, M., and Tindell, C. 1994. **Qualitative Methods in Psychology: A research guide**. Philadelphia, UA: Open University.
- Bell, B. 1993. **Taking into Account Students' Thinking: A Teacher Development Guide**. Hamilton, New Zealand: Centre for Science and Mathematics Education Research, University of Waikato.
- Berk, L.E. and Winsler, A. 1995. **Scaffolding Children's Learning: Vygotsky and Early Childhood Education**. Washington D.C.: National Association for the Education of Youth Children.
- Best, J. W. and Kahn, J. V. 1993. **Research in Education**. Boston, London, Toronto, Tokyo, Singapore: Allyn and Bacon.
- Billett, S. 1996. Situated Learning: Bridging Sociocultural and Cognitive Theorising. **Learning and Instruction**. 6 (3): 263 – 280.
- Bingle, W. H. and Gaskell, P. J. 1994. Scientific Literacy for decision making and the social construction of knowledge. **Science Education**. 78(2): 185 – 201.
- Birch, A. 1997. **Developmental Psychology: From Infancy to Adulthood**. London, UK: Macmillan Press Ltd.
- Black, P., and William, D. 1998. Assessment and classroom learning. **Assessment in Education**. 5(1): 7 – 74.
- Bliss, J. and Ogborn, J. 1985. Children's choices of uses of energy. **European**

- Journal of Science Education.** 7: 195 – 203.
- Borton, J. 2003. Thailand's novel education policy **Asia Times** (September 24, 2003).
Available: http://www.atimes.com/atimes/Southeast_Asia/EI24Ae03.html,
January 07, 2004.
- Brook, A. and Driver, R. 1984. **Aspects of secondary students' understanding of energy.** Leeds, UK: Children's in Science Project, University of Leeds.
- Brown, J.S., Colin, A., and Duid, P. 1989. Situated Cognition and the culture of Learning. **Educational Researcher.** 18(1): 32 – 42.
- Bryman, A. 1988. **Quantity and Quality in Social Research.** London: Unwin Hyman.
- Bunge, M. 1973. Philosophical Inputs and Outputs of Technology. In Bugliarello, G. and Doner, D. (Eds.). **The History and Philosophy of Technology.** Chicago, USA: University of Illinois Press, 262 – 281.
- Bybee, R. W. and Sund, R. B. 1982. **Piaget for educators.** Columbus Ohio, USA: Charles E. Merrill Publishing Co. and A Bell & Howell Company.
- Bybee, R.W. 1997. **Achieving scientific literacy.** Portsmouth, New Hampshire, USA: Heinemann. 69 – 86
- Bybee, R.W. 1985. The Sisyphean question in science education: What should the scientifically and technologically literate person know, value and do-as a citizen? In Bybee, R.W. (Ed.), **Science-technology-society 1985 NSTA Yearbook.** Woshigton, D.C., USA: National Teacher Association. 79 – 93.
- Carter, G. R. 2002. Education Reform in Asian Countries: A Work in Progress

- Education update.** 44 (8). Available:
http://www.ascd.org/publications/ed_update/200212/carter.html
- Centre for Science and Technology Education Research (CSTER) (1989). **Energy For A Change: Teachers' Guide.** Hamilton, New Zealand: The Learning In Science Project (Energy), CSTER, University of Waikato.
- Chinawong, Kietisak. 2001. Science Teaching based on view of Science, Technology and Society by Using the Natural classroom. Bangkok, Thailand: Thesis of Master Degree in Science Teaching, Chulalongkorn University.
- Chotethaisong, Chuanchuen. 1996. **A Comparative Study of Learning Achieving and Attitudes Towards Pollution of Mathayomsuksa V Students between Science-Technology and Society (STS) Approach and The Conventional Approach.** Khonkaen, Thailand: Thesis of Master Degree in Science Education, Khonkaen University.
- Claxton, G. 1991. **Educating the inquiring mind: the challenge for school science.** New York, London: Harvester Wheatsheaf.
- Cobern, W.W. 1998. Science and a Social Constructivist View of Science Education. In Cobern, W.W. (Ed.). **Socio-cultural perspectives on Science Education: An International Dialogue.** Dordrecht, The Netherlands: Kluwer Academic Publishers. 7 – 24.
- Cohen, L. and Manion, L. 1994. **Research Methods in Education.** New York, USA: Routledge Falmer.
- Cohen, L., Manion, L. and Morrison, K. 2000. **Research Methods in Education.** London, UK: Routledge Falmer.

- Coll, R. K., France, B., and Taylor, I. 2005. The role of models/and analogies in science education: implications from research. **International Journal of Science Education**, 27 (2): 183 – 198.
- Confrey, J. 1995. How Compatible are Radical Constructivism, Sociocultural Approaches, and Social Constructivism? In Steffe, L.P. and Gale, J. (Eds.). **Constructivism in Education**. New Jersey, USA: Lawrence Erlbaum Associates, Inc., 185 – 226.
- Conway, R. 1994. Values in Technology Education. **International Journal of Technology Education and Design Education**. 4: 109 – 116.
- Cowie, B. M. 2000. **Formative Assessment in Science Classroom**. Hamilton, New Zealand: Thesis of Degree of Doctor of Philosophy in Science Education, University of Waikato.
- Cusick, P. A. 1987. Introduction. **Educational Administration Quarterly**. 23 (4): 11 – 24.
- Daro, P. 1996. Standards and Portfolio assessment In Baron, J.B. and Wolf, D.P. (Eds.). **Performance-Based Student Assessment: challenges and possibilities**. Chicago, IL, USA: University of Chicago Press. 239 – 260.
- de Vries, M. J. 1996. Technology Education: Beyond the ‘Technology is Applied Science’ Paradigm. **International Journal of Technology and Design Education**. 8(1): 1 – 6.
- Dempster, F.N. 1992. Using test to promote learning: a neglected classroom resource. **Journal of Research and Development in Education**. 25: 213 – 217.
- Denzin, N. K. and Lincoln, Y. K. 1994. **Handbook of Qualitative Research**.

Thousand Oak, USA: SAGE Publications.

- Diver, R., Asoko, H. Leach, J., Mortimer, E. & Scott, P. 1994a. Constructing scientific knowledge in the classroom. **Educational Researcher**, 23: 5 – 12.
- Dixon-Kraussm, L. 1996. **Vygotsky in the Classroom: Mediated Literacy Instruction and Assessment**. New York, USA: Longman.
- Driver, R., Leach, J., Millar, R., and Scott, P. 1996. **Young People's Images of Science**. Bristol, Philadelphia, USA: Open University Press.
- Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. 1994b. **Making sense of secondary science**. London, UK: Routledge.
- Duit, R. 1981. Students' notion about the energy concept – before and after physics instruction. In Jung, W.; Pfundt, H.; and Rhoneck (Eds.). **Proceedings of the international workshop 'Problems concerning students' representation of physics and chemistry knowledge'**. Ludwigsburg, West Germany, 268 – 319.
- Duit, R. 1983. Energy conceptions held by students and consequences for science teaching. In Helm, H. and Novak, J. (Eds.), **Misconceptions in science and mathematics**. Ithaca, New York, USA: Cornell University, 316 – 222.
- Duit, R. 1984. Learning the energy concept in school – empirical results from the Philippines and West Germany. **Physics Education**. 19: 59 – 66.
- Duit, R. and Haeussler, P. 1994. Learning and Teaching Energy. In Fensham, P., Gunstone, R. and White, R. (Eds.), **The Content of Science: A constructivist approach to its teaching and learning**. Bristol, Pennsylvania, USA: Falmer Press., 185 – 200

- Duit, R. and Treagust, D.F. 2003. Learning in Science – From Behaviourism Towards Social Constructivism and Beyond, in Fraser, B. J. and Tobin, K.G. (eds.), **International Handbook of Science Education: Part one**, The Netherlands: Kluwer Academic Publishers, 3 – 26.
- Eijkelhof, H. 1994. Toward a Research Base for Teaching Ionizing Radiation in a Risk Perspective. In Solomon, J. and Aikenhead, G. (Eds.), **STS Education: International Perspective on Reform**. New York, USA: Teachers College Press, Columbia University. 205 -215.
- Eijkelhof, H. and Kortland, K. 1988. Broadening the aims of physics education. In Fensham, P. (Ed.) **Development and Dilemmas in Science Education**. London, UK: The Falmer Press. 282 – 305.
- Eijkelhof, H. and Lijnse, P. 1988. The role of research and development to improve STS education: experiences from the PLON project. **International journal of science education**. 10(4): 464 – 474.
- Erickson, F. 1987. Conceptions of School Culture: An Overview. **Educational Administration Quarterly**. 23 (4): 11 – 24.
- Fensham, P. 1988. Approaches to the teaching of STS in science education **International Journal of Science Education**. 10(4): 346 – 356.
- Fleming, R. 1988. Undergraduate science students' views on the relationship between Science, Technology and Society. **International Journal of Science Education**. 10(4): 449 – 463.
- Fontana, A. and Frey, J. H. 1994. Interviewing: the art of science. In Denzin, N. K. and Lincoln, Y. S. (Eds.). **Handbook of Qualitative Research**. California, London, New Delhi: Sage Publications. 361 – 256.

- Freybreg, P. and Osborne, R. 1985. Assumptions about Teaching and Learning. Osborne and Freyberge, P. (Eds.) **Learning in Science: The Implications of Children's Science**. Auckland, New Zealand: Hienmann, 81 – 90.
- Fry, G.W. 2002. The Evolution of Educational Reform in Thailand. **Paper presented at the second International Forum. Organized by the Office of the National Education Commission (ONEC), September 2 -5, 2002.** Available: <http://www.worldedreform.com/intercon2/fly.pdf>, January 10, 2004.
- Gagne, R. M. 1977. **The Conditions of Learning**. New York, USA: Holt, Rinehart and Winston, Inc.
- Gair, J. and Stancliffe, D.T. 1988. Talking about toys: an investigation of children's ideas about force and energy. **Research in Science and Technological Education**. 6: 167 – 180.
- Gardner, P. L. 1994. The Relationship Between Technology and Science: Some Historical and Philosophical Reflections. **International Journal of Technology and Design Education**. 4: 123 – 153.
- Gardner, P. L. 1997. The Root of Technology and Science: A Philosophical and Historical View. **International Journal of Technology and Design Education**. 7: 13 – 20.
- Glaser, R. 1990. Toward new models for assessment. **International Journal of Educational Research**. 14(5): 475 – 483.
- Hansen, K. 1997. Science and Technology as Social Relations Towards a Philosophy of Technology for Liberal Education. **International Journal of Technology and Design Education**. 7: 49 – 63.

- Hansen, R., and Froelich, M. 1994. Defining Technology and Technological Education: A Crisis, or Cause for Celebration. **International Journal of Technology and Design Education**. 4: 179 – 207.
- Hobson, A. 1982. **Physics and human affairs**. New York, USA: Wiley
- Hodson, D. and Hodson, J. 1998. From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science **School Science Review**. 79 (289): 33 – 41.
- Holbrook, J., Craven, J., and Lutz, M. 1996. STS in Developing Countries in the Pacific. **Science/Technology/Society As Reform In Science Education**. In Yager (Ed.). New York, USA.: State of University of New York Press.: 280 – 297.
- Hunt, A. 1988. SATIS approaches to STS. **International Journal of Science Education**. 10(4): 409 – 420.
- Institute for the Promotion of Teaching Science and Technology (IPST). 2002. **The Manual of content of science learning**. Bangkok, Thailand: Curusapha ladphoa.
- Jegade, O. J. 1988. The development of the science, technology and society curricula in Nigeria. **International Journal of Science Education**. 10(4): 399 – 408.
- Jenkins, E.W. 1990. Scientific literacy and school science education. **School Science Review**. 71(25): 43 – 51.
- Johnson, A. 1992. Educational Options for the Future of Thailand. **TDRI Quarterly Review**. 7(1): 3 – 7. Available:
http://info.tdri.or.th/library/quarterly/text/m92_1.htm

- Jones, A. (in press.) The Role and Place of Technology in Science Education.
- Jones, A. 1997. Recent Research in Learning Technological Concepts and Processes. **International Journal of Technology and Design Education**. 7: 83 – 96.
- Jones, A. 2002. Reliability and Validity for Qualitative Research in Education. **Document for Classforum Waikato University: Kasetsart University Program**. Available:
<https://classforum.waikato.ac.nz/classforum?233@231.WVaYaR02kzn.21496@.2cb9587d!enclosure=.2cb9587e>
- Jones, A. 2003. The Development of a National Curriculum in Technology for New Zealand. **International journal of technology and Design Education**. 13: 83 – 99.
- Jones, A. and Kirk, C. M. 1990. Introducing technological applications into the physics classroom: help or hindrance for learning? **International journal of science education**. 12(5): 481 – 490.
- Jones, A., Bell, B., and Carr, M. 1995. The Development of the Recent National New Zealand Science Curriculum. **Studies in Science Education**. 26: 73 – 105.
- Kaewdaeng, R. 2003. Educational Reform in Thailand: the view from an insider in Story by Fredrickson, T. **The Bangkok Post**. Available:
<http://www.bangkokpost.net/education/site2003/cvse2303.htm>
- Kiraly, D. 2000. **A Social Constructivist Approach to Translator Education: Empowerment from Theory to Practice**. Manchester, UK: St. Jerome Publishing.
- Kirkwood, V. and Carr, M. (1989). A valuable teaching approach: some insights from

- LISP (Energy). **Physics Education**. 24, 332 – 334.
- Kortland, K. 1992. Environmental education: Sustainable development and decision making. In Yager, R. E. (Ed.). **The status of STS: Reform efforts around the world**. Petersfield, UK: International Council of Associations for Science Education. 32 – 39.
- Kortland, K. 1992. Environmental Education: Sustainable development and decision-making. In Yager, R. E. (Ed.), **The Status of STS reform efforts around the world: ICASE Yearbook 1992**. Peterfield, UK: International Council of Association for Science Education. 32 – 39.
- Kortland, K. 1995. Decision-making on Science-related Social Issues: The Case of Garbage in Physical Science – A Problem-posing Approach. In Westford, G., Osborne, J., and Scott, P. (Eds.). **Research in Science Education in Europe: Current Issues and Themes**. London, UK: The Falmer Press, 115 – 125.
- Kortland, K. 1996. An STS Case Study about Students' Decision Making on the Waste Issue. **Science Education**. 80(6): 673 – 689.
- Lather, P. 1992. Critical Frames in Educational Research: Feminist and Post-structural Perspectives. **Theory Into Practice**. XXXI(2): 87 – 99.
- Lave, J. 1991. Situated learning in communities of practice. In Resnick, L. B., Levine, J. M., and Teasley, S. D. (Eds.). **Shared cognition: Thinking as social practice, perspectives on socially shared cognition**. Washington, D.C., USA: American Psychology Association. 63 – 82.
- Lave, J. and Wenger, E. 1991. **Situated Learning: Legitimate peripheral participation**. Cambridge, UK: Cambridge University Press.
- Layton, D. 1994. STS in the School Curriculum: A Movement Overtaken by

- History. In Solomon, J. and Aikenhead, G. (Eds.), **STS Education: International Perspective on Reform**. New York, USA: Teachers College Press, Columbia University. 32 – 44.
- Lefrancois, G.R. 1994. **Psychology for Teaching: a bear always, usually, sometimes, rarely, never, always faces the front will not commit himself just now, faces the future**. California, USA: Wadsworth.
- Letherman, R. 1973. Energy is not ability to do work. **Physics Teacher**. 11, 15 – 18.
- Liligeto, A. G. 2001. **Perceptions of Technology and Technology Education in Fuji and the Solomon Islands**. Hamilton, New Zealand: Thesis of Doctor of Philosophy, The University of Waikato.
- Lincoln, Y. S. and Guba, E. G. 1985. **Naturalistic inquiry**. Beverly Hills, London, New Delhi: Sage Publications.
- Lythcott, J. and Duschl, R. 1990. Qualitative Research: from methods to conclusions. **Science Education**. 74(4): 445 – 460.
- Mather, V. J. 1995. **Students' Concepts of Technology and Technology Education: Implications for Practice**. Hamilton, New Zealand: Thesis of Master Education, The University of Waikato.
- McCormick, R. 1993. The Evolution of Current Practice in Technology Education. In McCormick, R., Murphy, P., and Harrison, M. (Eds.). **Teaching and Learning Technology**. Wokingham, UK: The Open University.
- Merriam, S. B. 1988. **Case study research in education**. San Francisco, USA: Jossey-Bass.

- Mills, R.P. 1996. State wide Portfolio Assessment: the Vermont Experience. In Baron, J.B. and Wolf, D.P. (Eds.). **Performance-Based Student Assessment: challenges and possibilities**. Chicago, IL, USA: University of Chicago Press. 192 – 214.
- Ministry of Education (MOE). 1996. **Education Reform at the Ministry of Education Thailand**. Bangkok, Thailand: External Relations Division, Office of the Performance Secretary.
- Ministry of Education (MOE). 2002. **Basic Education Curriculum B.E. 2544 (A.D. 2001)**. Bangkok, Thailand: The Express Transportation Organization of Thailand.
- National Economic and Social Development Board (NESDB). 2002. **Government of Thailand the Nine National Economic and Social Development Plan (2002 – 2006)**. Bangkok, Thailand: Kurusapa press.
- National Science Teachers Association (NSTA). 1993. Science/Technology/Society: A New Effort for Providing Appropriate Science for All. **The Science, Technology, Society, Movement**. In Yager, R. E. (Ed.). Washigton DC: Reproductions Incorporated.
- Naughton, J. 1992. What is technology? In McCommick, R., Newey, C., and Sparkes, J. (Eds.), **Technology for Technology Education**. UK: The Open University.
- Nganunu, M. 1988. An attempt to write a science curriculum with social relevant for Botswana. **International Journal of Science Education**. 10(4): 441 – 448.
- Office of the National Culture Commission (ONCC). 2004. **Culture of Thai living**

- style (Vat-ta-na-thum-ras-sa-don).** Available:
<http://technology.thai.net/culture/onccthai2.html>
- Office of the National Education Commission (ONEC). 1998a. **Crisis of Thai Science Education.** Bangkok: ONEC.
- Office of the National Education Commission (ONEC). 1998b. **Education in Thailand 1998.** Bangkok: ONEC. Available:
http://www.onec.go.th/onec_pub/edu1998/pdf/chapter.pdf, January 10, 2004.
- Office of the National Education Commission (ONEC). 1999. **Education in Thailand 1999.** Bangkok, Thailand: Wattana Panit Printing & Publishing Company Limited. Available:
http://www.onec.go.th/HTML_99/ONEC_PUB/Book/YR42/ed_in_thailand99
- Office of the National Education Commission (ONEC). 2000a. **Learning Reform: A Learner-Centred Approach.** Bangkok, Thailand: Wattana Panit Printing & Publishing Company Limited.
- Office of the National Education Commission (ONEC). 2000b. **National Education Act B.E. 2542 (1999).** Bangkok: Office of the Prime Minister Kingdom of Thailand.
- Osborne, J. and Goldring, H. 1994. Students' difficulties with energy and related concepts. **Physics Education**, 29: 26 – 32.
- Osborne, J.F. 1996. Beyond Constructivism. **Science Education**. 80 (1): 53 – 82.
- Packer, M.J. and Goicoechea, J. 2000. Sociocultural and Constructivist Theories of Learning: Ontology, Not Just Epistemology. **Educational Psychologist**. 35(4): 227 – 241.

- Patronis, T., Potari, D., and Spiliotopoulou, V. 1999. Students' argumentation in decision-making on a socio-scientific issue: implications for teaching. **International Journal of Science Education**. 21(7): 745 – 754.
- Patton, M.Q. 1990. **Qualitative evaluation and research methods (2nd ed.)**. Newbury Park, California, USA: Sage Publication
- Pedretti, E. 1996. Learning about Science, Technology, and Society (STS) Through an Action Research Project: Co – Constructing an Issues-Based Model for STS Education. **School Science & Mathematics**. 96(8):
- Pitiyanuwat, S. and Anantrasirichai, A. 2002. Curriculum and Learning Reform in Thailand **Paper presented at Invitational Curriculum Policy Seminar: School Based Curriculum Renewal for the Knowledge Society Developing Capacity for New Times**, Hong Kong, 14 – 16 November 2002. Available: <http://ci-lab.ied.edu.hk>
- Pitiyanuwat, S. and Sujiva, S. 2000. Civics and Values Education in Thailand: Documentary Analysis. **Asia Pacific Journal of Education**. 20(1): 82 – 92.
- Premasiri, P.D. 1996. Humanization of Development: A Theravada Buddhist Perspective. In Saraswati, B. (Ed.). **Interface of Cultural Identity Development**. New Delhi, India: IGNCA and D. K. Printworld Pvt. Ltd., Available: http://ignca.nic.in/ls_03005.htm
- Ratcliffe, M. 1995. Adolescent Decision-making, by Individuals and Groups, about Science-related Societal Issues. In Westford, G., Osborne, J., and Scott, P. (Eds.). **Research in Science Education in Europe: Current Issues and Themes**. London, UK: The Falmer Press, 126 – 140.

- Ratcliffe, M. 1997. Pupil decision-making about socio-scientific issues within the science curriculum'. **International Journal of Science Education**. 19(2): 167 – 182.
- Rogoff, B. 1995. Observing sociocultural activity on three planes: participatory appropriation, guided participation, and apprenticeship. In Wertsch, J.V.; Del Rio, P.D.; and Alvarez, A. (Eds.). **Sociocultural Studies of Mind**. New York, USA: Cambridge University Press. 139 – 164.
- Rollnick, M. 1998. The Influence of Language on the Second Language Teaching and Learning of Science. In Cobern, W.W. (Ed.). **Socio-cultural perspectives on Science Education: An International Dialogue**. Dordrecht, The Netherlands: Kluwer Academic Publishers. 121 – 138.
- Rosenthal, R. D. 1989. Two Approaches to Science-technology-Society (S-T-S) Education. **Science Education**. 73(5): 581 – 589.
- Ryan, A.G. 1992. VOSTS: A Way of Expanding Classroom Assessment to Meet The STS Agenda in Secondary School Science. In Yager, R.E. (Ed.) **ICASE Yearbook 1992: The Status of Science-Technology-Society Reform Efforts around the world**. Peterfield, UK: ICASE Publication. 57 – 66.
- Sarantakos, S. 1993. **Social Research**. Melbourne, Australia: Macmilan Education Australia PTY LTD.
- Sengsook, Rattana. 1997. **A Study of Mathayomsuksa 1-6 Students' Conceptions of Energy in Donchimpleepittayacom School, Amphoe Bangnumpeaw, Changwat Chachoengsao : a case study**. Bangkok, Thailand: Thesis of Master Degree in Science Teaching, Kasetsart University.
- Shield, G. 1996. Formative Influences on Technology Education: The Search for an

- Effective Compromise in Curriculum Innovation. **Journal of Technology Education**. 8(1): 50 – 60.
- Shotter, J. 1992. In dialogue: Social constructivism and radical constructivism. A **paper for conference on Alternative Epistemologies in Education**. Georgia, USA.
- Shulman, L. S. 1987. Knowledge and Teaching: Foundations of the New Reform. **Harvard Educational Review**, 57 (1): 1 – 22.
- Sinlarat, P. 1999. Alternative forms of in-service training in the redevelopment of teachers. **Education Management and Financing in Thailand: Review and Recommendations Research Papers, Vol II**. Bangkok, Thailand: UNESCO.
- Slavin, R.E. 1990. **Cooperative Learning: Theory, Research and Practice**. Englewood Cliffs, New Jersey, USA: Prentice Hall.
- Smith, J.K. 1992. Interpretive inquiry: A Practical and Moral Activity. **Theory into Practice**. XXXI (2): 100 – 106.
- Solomon, J. 1983a. Learning about energy: how students think in two domains. **International Journal of Science Education**. 5: 45 – 59.
- Solomon, J. 1983b. Messy, contradictory and obstinately persistent: a study of children's out-of-school ideas about energy. **School Science Review**. 65: 225 – 233.
- Solomon, J. 1983c. Teaching about energy. **Physics Education**. 18: 205.
- Solomon, J. 1985. Teaching the conservation of energy. **Physics Education**. 113 – 114.

- Solomon, J. 1988. Science technology and society courses: tools for thinking about social issues. **International Journal of Science Education**. 10(4): 379 – 387.
- Solomon, J. 1992. The classroom discussion of science-based social issues presented on television: knowledge, attitudes and values. **International Journal of Science Education**. 14(4): 431 – 444.
- Solomon, J. 1994. Knowledge, Values and the Public Choice of Science Knowledge. In Solomon, J. and Aikenhead, G. (Eds.), **STS Education: International Perspective on Reform**. New York, USA: Teachers College Press, Columbia University. 99 -110.
- Soydthurum, P. 1990. **Secondary School Science Education in Thailand**. Bangkok, Thailand: Ministry of Education.
- Spauld, A. D. 1988. Oral history. In Keeves, J. P. (Ed.) **Educational Research, Methodology, and Measurement; International Handbook**. Oxford: Pergamon Press. 75 – 78.
- Stiggins, R.J., Griswold, M.M., and Wikelund, K. R. 1989. Measuring thinking skills through classroom assessment. **Journal of Educational Measurement**. 26: 233 – 246.
- Swernofsky, N. 1989. **Making Technology Work**. New York, USA: Albany.
- Tan, M. C. 1988. Towards relevance in Science education: Philippine context. **International Journal of Science Education**. 10(4): 431 – 440.
- Taweasate, W. and Nuensakul, S. 2000. **Kaan Mueng Lae Kaan Pokkrong Thai (Thai Government and Politics)**. Bangkok, Thailand: Ramkhamhaeng

- University. Available: <http://e-book.ram.edu/e-book/p/ps110/ps110.htm>
- The Ministry of Education (MOE). 2004. **THAI EDUCATION IN BRIEF ITS PAST, PRESENT, AND FUTURE**. Available: http://www.moe.go.th/weberd/ministry__of_education.htm
- The Nation**. 2001. Bangkok: August 28, 2001. Available: <http://www.theNationmultimedia.com>
- Titthummo, Jarun. 2004. **The development of mind (Pattana Jitta)**. Available: <http://www.jarun.org/42-10.htm>
- Tobin, K. 2000. Interpretive Research in Science Education. In Kelly, A. E. and Lesh, R. A. (Eds.). **Handbook of Research Design in Mathematics and Science Education**. Mahwah, USA: Lawrence Erlbaum Associates.
- Tobin, K. 1990. Social constructivist perspectives on the reform of science education **The Australian Science Teachers Journal**. 36(4): 29 – 35.
- Tobin, K. and Tippins, D. 1993. Constructivism as a referent for teaching and learning. In Tobin, k. (Eds.), **The practice of constructivism in science education**. Washington, DC: AAAS Press: 3 – 21.
- Trends in International Mathematics and Science Study (TIMSS) 1999. Available: <http://timss.bc.edu/timss1999.html>
- Trumper, R. 1990a. Being constructive: an alternative approach to the teaching of the energy concept – part one. **International Journal of Science Education**, 12(4): 343 – 354.
- Trumper, R. 1990b. Energy and a constructivist way of teaching. **Physics Education**, 25: 208 – 212.

- Trumper, R. 1993. Children's energy concepts: a cross – age study. **International Journal of Science Education**, 15 (2): 139 – 148.
- Tsai, C. 2000. The Effects of STS-oriented Instruction on female tenth graders' cognitive structure outcomes and the role of student scientific epistemological beliefs. **International Journal of Science Education**, 22(10): 1099 – 1115.
- Von Glaserfeld, E. V. 1993. Questions and answers about radical constructivism. In Tobin, K. (Eds.) **The practice of constructivism in science education**. Washington, DC: AAAS Press: 23 – 38.
- Von Glaserfeld, V. E. 1992. A Constructivist's view of learning and teaching. In Duit, R.; Goldberg, F.; and Niedderer, H. (Eds.) **Research in Physics Learning: Theoretical Issues and Empirical Studies**. Keil, Germany: Institute für die Pädagogik der Naturwissenschaften an der Universität, 29 -39.
- Vygotsky, L.S. 1978. **Mind in Society: The Development of Higher Psychological processes**. London: Harvard University
- Vygotsky, L.S. 1986. **Thought and Language**. Cambridge, Massachusetts, USA.: MIT Press
- Watchamul, C. 1998. **Public Acceptance in Using Nuclear Energy for Electricity Generation in Thailand: Case Study of People in Pathiew District, Chumporn Province**. Bangkok: Thesis, Chulalongkorn University.
- Watts, D.B. 1983. Some alternative views of energy. **Physics Education**. 18: 213 – 217.
- Watts, D.B. and Gilbert, J.K. 1983. Enigmas in school science: students' conceptions for scientifically associated world. **Research in Science and Technological**

- Education.** 1(2): 161 – 171.
- Wertsch, J. V. 1985. **Vygotsky and Social Formation of Mind.** Cambridge, Massachusetts, USA. : Harvard University Press.
- Wertsch, J.V. 1991. **Voices of the mind: a sociocultural approach to mediated action.** Cambridge, Massachusetts, USA. : Harvard University Press.
- Wertsch, J.V. 1995. The needs for action in sociocultural research. In Wertsch, J.V.; Del Rio, P.D.; and Alvarez, A. (Eds.). **Sociocultural Studies of Mind.** New York, USA: Cambridge University Press. 56 – 74.
- Wertsch, J.V. and Toma, C. 1995. Discourse and Learning in the Classroom: A Sociocultural Approach. In Steffe, L.P. and Gale, J. (Eds.). **Constructivism in Education.** New Jersey, USA: Lawrence Erlbaum Associates, Inc. 159 – 174.
- Wertsch, J.V.; Del Rio, P.D.; and Alvarez, A. 1995. Sociocultural studies: history, action, and mediation. In Wertsch, J.V.; Del Rio, P.D.; and Alvarez, A. (Eds.). **Sociocultural Studies of Mind.** New York, USA: Cambridge University Press. 1 – 36.
- Wheldall, K. and Merret, F. 1984. **Positive Teaching: The Behavioural Approach.** London, Boston: Allen&Unwin.
- Wisadavet, W. 1996. Cultural Identity and Development Process in Thailand. In Saraswati, B. (Ed.). **Interface of Cultural Identity Development.** New Delhi, India: IGNC A and D. K. Printworld Pvt. Ltd., Available: http://ignca.nic.in/ls_03022.htm
- Wolf, R. M. 1988. Questionnaires. In Keeves, J.P. (Ed.). **Educational Research, Methodology, and Measurement: International Handbook.** Oxford, UK: Pergamon Press. 478 – 482.

- Yager, R. E. 1996a. History of Science/Technology/Society as Reform in the United States. **Science/Technology/Society As Reform In Science Education**. Yager (Ed.). New York, USA: State of University of New York Press. 3 – 15.
- Yager, R. E. 1996b. Meaning of STS for science Teachers. **Science/Technology/Society As Reform In Science Education**. Yager (Ed.). New York, USA: State of University of New York Press. 16 – 24.
- Yager, R. E., Mackinnu, and Blunck, S. M. 1992. Science/Technology/Society As Reform of Science in the Elementary School. **Journal of Elementary Science Education**, 4(1): 1 – 13.
- Yager, R.E. and Tamir, P. 1993. STS approaches: Reasons, intentions, accomplishments, and outcomes. **Science Education**. 77 (6): 637 – 658.
- Yuenyong, C., Sung-ong, S., and Veerapasong. T. 2005. Thai and New Zealand Students' Concept of the Definition of Energy and the Law of Energy Conservation. **The Kasetsart Journal (Social Science)**, 26(1): 42 – 51.
- Yutakom, N. 1997. **The Congruence of Perceptions and Behaviours Exhibited by Twelve Successful Middle School Teachers in Implementing Science/Technology/Society/Constructivist Practices in Iowa Scope, Sequence, and Coordination schools**. Iowa, USA: Dissertation of the Doctor of Philosophy degree in Science Education, The University of Iowa.
- Yutakom, N. 1999. Science teaching by using science, technology and society – STS model. **Journal of Education, Kasetsart University**, 14 (3): 29 – 48.
- Ziman, J. 1978. **Reliable knowledge: An exploration of the grounds for belief in science**. London, New York, Melbourne: Cambridge University Press.

ข้อคิดเห็น[c1]: Need to be corrected

Zohar, A., and Dori, Y. J. 2003. Higher Order Thinking Skills and Low-Achieving Students: Are They Mutually Exclusive?. **The Journal of the Learning Sciences**, 12(2): 145 – 181.

APPENDIXES

APPENDIX A
RESEARCH INSTRUMENTS

1. The Questionnaire of Student Energy Conception (QSEC)

Questionnaire of Student Energy Conception (QSEC)

Name: _____ Class _____ School: _____

This questionnaire sheet explores your personal opinion about energy related to issue of society and technology. Your opinion will be used to improve the energy unit in the future. These your responses will not be viewed by your teachers or by your school authorities. Thank you very much for your response.

1. Write 3 short sentences with the word “energy” in it as you understands or use the word energy.

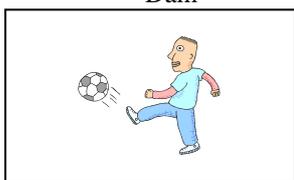
2. Give “formation energy” as much as you can

3. What do you understand by ‘conservation of energy’?

4. Look carefully at the following pictures. If you think that energy is involved tick the box and briefly explain what you think is happening.



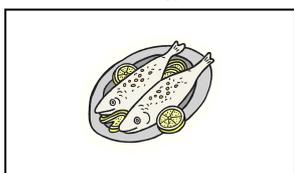
Dam



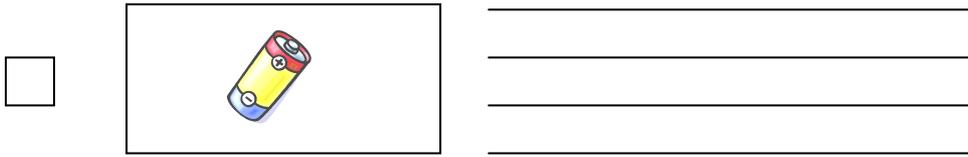
Soccer



Running



Food



Battery



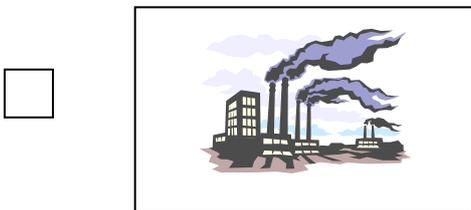
Gas station



Coal

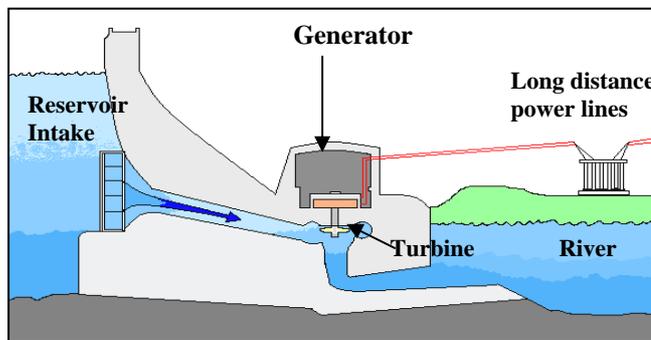


Power station



Factory

5. Here is a diagram showing how a hydro electric power station operates. The water behind the dam flows through the intake and into a pipe called a penstock. The water pushes against blades in a turbine, causing them to turn. The turbine spins a generator to produce electricity. The electricity can then travel over long distance electric lines to your home and to your school.



Describe what energy transformation occur in the process of generating power from the hydro power plant.

6. Energy can be transformed from one form to another. Can you describe energy transformation in each picture below?

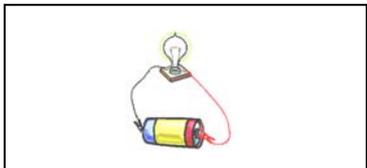
Pictures	Energy transformation
Blender 
Lamp 
Television 

7. Electrical energy is used to power a lamp.

7a) Tick in the box the statements that are true.

- Is the amount of light energy produced more than the amount of electrical energy used?
- Is the amount of light energy produced less than the amount of electrical energy used?
- Is the amount of light energy produced the same as the amount of electrical energy used?

7b) Label the following diagram to show the energy transformations taking place somewhere in this picture.

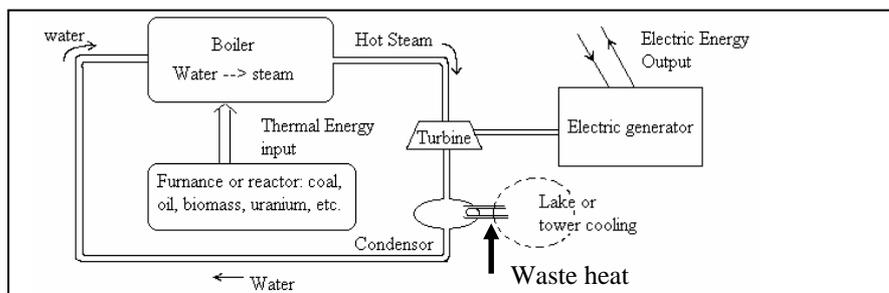


8. Which two of the four following situations are examples of law of conservation energy?

- (a) Dum has changed the incandescent bulbs to energy-saving fluorescent tubes. He has found them cheaper in the long run as they last longer and they are much brighter.
- (b) Ann touches the back of a fan. She found that it is hot. So, she understands that input energy (electric energy) was not lost but it has been transformed into kinetic energy of the fan and heat energy in the motor.
- (c) Daeng's family switch off the lights and all electrical points when no one is in the room, such as television and the computer, before going to the bed every night. Leaving them on stand by mode will still use up energy.
- (d) The officer of the Num-pong steam power plant explains to students that the power plant uses high pressure steam at 500 C° as the force for turning the turbine. The turbine then turns the electric generator. This process provides electricity, but it is not 100 percent of input energy. The remaining input energy is transformed in to thermal energy of the low pressure water and heat of the turbine.

9. Some two-thirds of the energy that goes into a steam-electric power plant comes out as waste heat. Look carefully at the diagram shown.

10a) Describe how this waste heat can be used. (You may use diagram as part of your answer)



10b) Would we still call waste heat thermal pollution if it is used? Why?

10. We have lots of sunlight every day in Thailand. In your opinion, how can we catch sunlight as solar energy to convert into another energy form for using in everyday life? Give an example and describe or draw a labelled diagram.

11. In the scientific view, the total amount of energy is always constant. It could be argued that it is therefore not necessary to conserve energy. If this is true then why we are always trying to save energy?

2. The Questionnaire for Students' idea about Energy related Technological and Societal issues (QSETS)

Questionnaire for Students' idea about Energy related Technological and Societal issues (QSETS)

Name: _____ Class _____ School _____

This questionnaire sheet explores your personal opinion about energy related to issue of society and technology. Your opinion will be used to improve the energy unit in the future. These your responses will not be viewed by your teachers or by your school authorities. Thank you very much for your response.

Instruction: Read the following question and then circle the statement you agree with.

1. Should Thai government give research money to scientists to study sustainable energy or explore the unknowns of energy resources?
 - (a) I don't understand the question.
 - (b) I don't know enough about this subject to make a choice.

Money should be spent on these research:

 - (c) So that Thailand does not fall behind other countries and become dependent upon them.
 - (d) In order to satisfy the human urge to know the unknown: that is, to satisfy scientific curiosity.
 - (e) Even though it's often impossible to tell ahead of time whether the research will be beneficial or not. It's an investment risk, but we should take it.
 - (f) Only when the research is obviously useful to society.

Little or no money should be spent on research:

 - (g) Because the money could be spent on other things, such as investing for industry or helping Thai's unemployed.
 - (h) Because the other countries have already done about this kind of research and we can use their results.

(i) None of these choices fits my basic viewpoint. My view is _____

2. A country's politics affect scientists' study of energy. This happens because scientists are not isolated from their society. Do you agree or disagree? Why?

I don't understand the question.

 - (a) I don't know enough about this subject to make a choice.

I agree:

- (b) Because funding for energy comes mainly from governments which control the way the money is spent. Scientists sometimes have to lobby for funds.
- (c) Because government established the Ministry of Energy for studying about energy and so there is no need for extra research.
- (d) Because politics limits and controls scientists by telling them what research to do.
- (e) Because governments can force scientists to work on a project which scientists feel is wrong, and not allow the scientists to work on projects beneficial to society.
- (f) Because scientists are a part of society and are affected like everyone else.
- (g) Because scientists try to understand and help society and thus, because of their involvement and importance to society, scientists are closely tied to society.

I disagree:

- (h) Because scientific research has nothing to do with politics.
- (i) Because scientists are isolated from their society.
- (j) None of these choices fits my basic viewpoint. My view is _____

3. In Thailand, we do not need study research related to energy. We adopt knowledge and technology from other countries such as Japan, USA or Europe. This is useful for our country. Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree:

- (c) Because we must spend amounts of money but there is sometime nothing that is useful in society.
- (d) Because greater amounts of money should be spent on foundation education, industrial research and community industrial research (One Tumbol One Product).
- (e) Because it is more cost effective. Thailand does not spend any budget for research but we could still use technology that is imported from developed countries.

I disagree:

- (f) Because investment for studying research will develop Thai scientists' quality even though sometimes research will fail.
- (g) Because Thailand must import high cost of technology and this upset the balance of import and export trade.
- (h) Because we should develop energy technology stemming from our own requirements and to solve our local problems.
- (i) None of these choices fits my basic viewpoint. My view is _____

4. We have a large amount of sunlight everyday a year in Thailand. Should we develop our knowledge of solar cell technology which could be used to build solar power plant?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

Yes, we should

- (c) Because solar energy has the least effect on an environment.
- (d) Because solar energy is sustainable energy.
- (e) It is worth while in the long run because solar energy is has no cost even though there is a high cost to construct the solar power plant.
- (f) Thailand needs to use large amounts of energy in the future but currently energy resource is restricted.

No, we should not

- (g) Because it will take too much time to recover the constructing costs.
- (h) Because Thailand would spend a lot of money for constructing and taking care the power plants, but generate little energy.
- (i) None of these choices fits my basic viewpoint. My view is _____

5. The Mae-moa coal power plant has greatly polluted the air. Therefore it is a responsible decision to no produce electricity from coal power anymore. Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree:

- (c) We should save our country and its future generations.
- (d) Because the government have enough problems without the added problem of pollution.
- (e) Because pollution should be confined as much as possible. Spreading it around would only create more damage.

I disagree:

- (f) Because doesn't matter whether we will have the coal power plant if another country still produce pollution. The effects of pollution are global.
 - (g) Because the coal power plant is cheap and we have a lot of coal. That means we can gain more profit than other power plants.
 - (h) We still hope to use coal for generating power if scientists can create process of generating power to emit less pollution than before.
 - (i) The coal power plant produces cheap power plant. This helps the government to decrease the budget.
 - (j) It's hard to tell. We would help reduce our own pollution. But our government must make the decision based on economic growth.
- (k) None of these choices fits my basic viewpoint. My view is _____

6. Because scientists and engineers are the people who know the facts best, they should be the ones to decide what types of energy Thailand will use in the future (for example, nuclear, hydro, solar, or coal burning). Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree:

- (c) Because they have the training and facts which give them a better understanding of the issue.
- (d) Because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.
- (e) Because they have the training and facts which give them a better understanding; but the public should be involved - either informed or consulted.

I disagree:

- (f) The decision should be made equally; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society.
 - (g) The government should decide because the issue is basically a political one; but scientists and engineers should give advice.
 - (h) The public should decide because the decision affects everyone; but scientists and engineers should give advice.
 - (i) The public should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.
- (j) None of these choices fits my basic viewpoint. My view is _____

7. Knowledge and understanding about the science and technology of energy can help people make some moral decisions about generating power. Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree. Because energy science knowledge can help you make some decisions:

- (c) By making you more informed about technology and its effect in the environment. This background information can help you cope with the moral aspects of environment.
- (d) By providing background information; but moral decisions must be made by individuals.

I disagree. Energy science knowledge and technology cannot help you make moral decisions:

- (e) Because energy science knowledge and technology have nothing to do with moral decisions. What people do with the results is not the scientist's concern.
- (f) Because moral decisions are made solely on the basis of an individual's values and beliefs.
- (g) None of these choices fits my basic viewpoint. My view is _____

8. There have been protests against the use of coal, nuclear energy and dams for power generation because of worried about pollution, safety in process of generating power or using land. Energy science and technology knowledge offer a great deal of help in resolving these social problems. Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree:

- (c) Energy science knowledge and technology can certainly help to resolve these problems. The problems could use new ideas from energy science knowledge and new inventions from technology.
- (d) Science and technology can help resolve some social problems but not others.

I disagree:

- (e) It's not question of energy science knowledge and technology helping, but rather it is question of people using science and technology wisely and carefully.
- (f) It is hard to see how energy science knowledge and technology could help very much in resolving these problems. Social problems concerned human centred.
- (g) Science and technology only make social problem worse. It is the price we pay for advances in science and technology.

- (h) None of these choices fits my basic viewpoint. My view is _____

9. In your everyday life, knowledge of energy science and technology can help you to manage how to save energy in your house. Do you agree or disagree? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

I agree:

- (c) I would like to save energy because I know that although energy cannot be lost and destroyed but it is transformed into useful form.
- (d) I iron many clothes in the same time. I think that more electric energy will be conserved by ironing many clothes at the same time, then heating the iron for many garments at a time.
- (e) I do not place the hot food into the refrigerator because I understand that the refrigerator must use amount of energy for cooling food.
- (f) The knowledge of losing energy or any knowledge of energy science and technology makes me want to create an electrical device for saving energy.
- (g) I would like to save energy because I know whenever energy is used; energy will be transform into less useful and hard to reuse form.

I disagree:

- (h) Because what I learn in classroom is not enough for managing to save energy.
- (i) Although I understand knowledge, I cannot to force others to save energy, because management to save energy may disturb daily individual habits.
- (j) I cannot manage to save energy. I think that only scientists or engineers can do safely and efficiently this work.

- (k) None of these choices fits my basic viewpoint. My view is _____

10. Do you think Thailand should construct more power stations? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

Yes, we should because:

- (c) We have no choice. Because we consume increasing amounts of energy, we must construct power stations.

- (d) We need to reserve energy for future use, although we have enough electrical energy at present.
- (e) At the present, we do not have enough electrical energy, so we must buy it from other countries such as Burma and Laos.
- (f) Electrical energy is a part of our life. Without it we cannot function in everyday life; we cannot cook, watch television, or use the internet etc.

No, we should not because:

- (g) We feel we do have enough energy. We should save energy rather than plan to construct a new power plant.
- (h) Constructing a power station usually generates environment problems such as pollution. We should decrease electrical energy use in order to decrease other problems and decrease the budget which is needed.
- (l) None of these choices fits my basic viewpoint. My view is _____

11. Do you think we use too much energy? Why?

- (a) I don't understand the question.
- (b) I don't know enough about this subject to make a choice.

Yes, I think so because:

- (c) I think that we don't need to turn on the lamp on day time but most people usually do that.
- (d) I think that most people perceive that energy is public property therefore they don't need to save energy.
- (e) I think that most people don't care about the difficulty of generating energy therefore they aren't aware of the need to save energy.
- (f) I think that people don't pay attention to the fact that increased consumption of energy has caused environmental damage.
- (g) I think that people don't see the need for using sustainable energy.

No, I don't think so because:

- (h) I think that people have to pay money for their own energy use. They can use energy as much as they can afford.
- (i) I think that energy will never run out. We can create another method for generating power if the present energy resource runs out.
- (j) I think that I perform only a small act of energy use; therefore it does not affect energy use in the whole country.
- (k) None of these choices fits my basic viewpoint. My view is _____

3. The Questionnaire for Teacher Energy Perception (QTEP)

Questionnaire for Teacher Energy Perception (QTEP)

Personal Data

1. Gender:

- Male Female

2. Qualifications:

- Bachelor of
- Master of
- Doctor of
- Others.....

3. Teaching experience:

1. Less than 5 years 2. 5 – 10 years 3. More than 10 years

4. Expert in subjects:

Your Opinion.

1. In your opinion, what are the important goals of energy teaching?
.....
.....
2. How and what the definitions of “the law of energy conservation” should be described to Grade 9 students?
.....
.....
3. What should we explain to students why people need to save energy?
.....
.....
4. In your opinion, what are the main types of transformation in the process of generating power in a hydro power station that should be learned by Grade 9 students?
.....
.....
5. “Some teachers told me that the energy is difficult concept.” Do you agree or disagree with this statement? Why?
 - Agree. Because
 -
 - Disagree. Because
 -
6. “Some teachers found that students confused what energy is.” What would you describe to students as the fundamental concepts for studying energy?
.....
.....
7. What is the importance of each of these aspects of teaching in being able to enhance student understanding of energy concepts and accomplish the goal of science education?
Circle a position along the scale after each item to indicate your answer.

Items	Your opinion			
	Not important	2	3	Very important
(1) Teach energy concepts starting from easy concepts moving to more difficult concepts.	1	2	3	4
(2) Explore student prior knowledge which enhances their energy learning.	1	2	3	4
(3) Teach energy concepts related to community.	1	2	3	4
(4) Empower students to think themselves about energy concept related to social issues.	1	2	3	4
(5) Teach energy concepts related student experiences.	1	2	3	4
(6) Inform students of learning objectives before the lessons	1	2	3	4
(7) Teach energy concepts related to technology.	1	2	3	4
(8) Teach energy concepts with emphasis on hands on and group activities.	1	2	3	4
(9) Use various teaching strategies to support student understanding of scientists’ ideas about energy concept.	1	2	3	4
(10) Teach energy concepts related to reporting about energy issued found in the mass media.	1	2	3	4
(11) Energy teaching emphasizes integration between disciplines (e.g. Physics, Chemistry, Biology and others).	1	2	3	4
(12) Energy teaching emphasizes experimentation.	1	2	3	4
(13) Empower students to be able to think, act, and solve problems of energy concept by themselves.	1	2	3	4
I think that there are others.				

4. Energy Test

1. What main of forms are given by battery?
 - a) Chemical potential and electric energy
 - b) Radiant and electric energy
 - c) Gravitational potential and electric energy
 - c) Magnetic and electric energy
 Answer: a

2. What does form of energy result when protons and neutrons are arranged into atomic nuclei?
 - a) Radiant energy
 - b) Nuclear energy
 - c) Electric energy
 - d) Chemical energy
 Answer: b

3. Select choice that does not give the kinetic energy.
 - a) Molecular of air
 - b) a pen is placed on the table
 - c) Light
 - d) a car is moving
 Answer: b

4. What form of energy does water reservoir has?
 - a) Kinetic energy
 - b) Electric energy
 - c) Gravitational potential energy
 - c) Water energy
 Answer: c

5. When you walk up stair, you increase your gravitational energy. This energy must come from somewhere. Where did it come from?
 - a) Kinetic energy
 - b) Heat energy
 - c) Chemical potential energy
 - d) Elastic potential energy
 Answer: c

6. Select choice that is renewable energy source.
 - a) Coal
 - b) Natural gas
 - c) Nuclear energy sources
 - c) Water energy sources
 Answer: d

7. Biogas is one of renewable energy sources that resulting from manure and organic matter are left to rot in a closed tank. What gas is given off?
 - a) Methane
 - b) Propane
 - c) NGV
 - d) Gasohol
 Answer: a

8. The prices of fossil petrol rise substantially. It might be time for use renewable energy. What kind of renewable energy would be used urgently in Thailand? Why?
 - a) Use light energy because solar car can be driven without petrol.
 - b) Use biomass because Thailand has amount of crop that is fermented to give alcohol, which is used as a fuel.
 - c) Use NGV gas because Thailand has sources of NGV gas. This means that it gives the lower cost of energy than petrol.
 - d) Use electric energy because electric car can be driven without petrol.
 Answer: b

9. Select the best reason why the solar energy should be used in Thailand.
 - a) There are three seasons in Thailand.
 - b) There is a large amount of sunlight everyday a year in Thailand.
 - c) There is a short rainy season in Thailand.
 - d) There is a long winter season in Thailand.
 Answer: b

10. Select below an activity that is the most consuming energy from petrol.
 - a) Transportation
 - b) Agriculture
 - b) Industry
 - d) Generating power
 Answer: a

11. What is energy the resulting from the ability of to do some kinds of work?
 - a) Potential energy
 - b) Kinetic energy
 - c) Mechanical energy
 - d) Nuclear energy
 Answer: a

12. The scientific knowledge stated that “the total of energy always stays the same”, so why people need to save energy. Which scientific idea about energy does explain this argument?
- Because although energy stays the same, people should save energy for use in the long run.
 - Because shortage of budget. Energy saving is budget saving.
 - Because energy might run out in the future.
 - Because energy can be transformed into non-useful forms of energy (e.g. waste heat)

Answer: d

13. Which one is the nature of energy that affects energy use?
- Energy can be transformed from one form to other forms of energy.
 - All of energy in its sources can never be used.
 - Energy use always gives pollutions.
 - Energy sources cannot be replaced when energy are used.

Answer: b

14. What are the three main forms of energy resulting from turning on the television?

- Heat, mechanical, and light energy
- Mechanical, heat, and sound energy
- Heat, sound, and light energy
- Mechanical, sound and wave energy

Answer: c

15. While Daeng is ironing her shirts, she thinks of her scientific knowledge that she just learn from school. She told her mother that all of electric energy flowing in the iron would not be transformed to heat of iron. What the scientific knowledge is Daeng considering?

- The law of energy conservation
- Energy transformation
- The second law of thermodynamics
- Heat conduction

Answer: c

16. Which two of the four following situations are examples of law of conservation energy?

- Dum has changed the incandescent bulbs to energy-saving fluorescent tubes. He has found them cheaper in the long run as they last longer and they are much brighter.
- Ann touches the back of a fan. She found that it is hot. So, she understands that input energy (electric energy) has been transformed into kinetic energy of the fan and heat energy in the motor.
- Daeng’s family switch off the lights and all electrical points when no one is in the room, such as television and the computer, before going to the bed every night. Leaving them on stand by mode will still use up energy.
- The officer of the Num-pong steam power plant explains to students that the power plant uses high pressure steam at 500 C° as the force for turning the turbine. The turbine then turns the electric generator. This process provides electricity, but it is not 100 percent of input energy. The remaining input energy is transformed in to thermal energy of the low pressure water and heat of the turbine.

a) 1, 2

b) 3, 4

c) 2, 4

d) 1, 3

Answer: c

17. “Energy is transformed from one form to another form but the total amount of amount of energy stays the same.” What is this scientific concept?

- The law of energy conservation
- Energy transformation
- Entropy
- The law of nature of energy

Answer: a

18. Electric energy is used to power a lamp. Select the statements that are true.
- The amount of light energy produced more than the amount of electrical energy used.
 - The amount of light energy produced less than the amount of electrical energy used.
 - The amount of light energy produced the same as the amount of electrical energy used.
 - The amount of light energy produced less than or the same as the amount of electrical energy used.
- Answer: b
19. What are the most two devices to induce electric current?
- Ammeter and wires
 - Coil and magnetic
 - Coil and wires
 - Ammeter and magnetic
- Answer: b
20. Select the most important factor to generating power.
- A number of copper coil
 - Velocity of turbine
 - Direction of magnetic field
 - Direction of turbine turning
- Answer: a
21. The Mae Moh released the serious level of air pollution in 1992 and 1999. That situation hurt a number of people, and destroyed crop plant and cattle. What is kind of gas emitted?
- Carbon dioxide
 - Sulfur dioxide
 - Carbon monoxide
 - Sulfur monoxide
- Answer: b
22. Select the statement that is not effect of air pollution that released from the Mae moh power plant.
- Increased the PH value of soil and water.
 - People sick as the Numoconiosease.
 - Acid rain speeds up the corrosion of metals.
 - The water reservoir becomes contaminated with dissolved metals.
- Answer: a
23. Select a choice that is the best explanation of energy transformation resulting from the hydro generating power.
- Water energy → electric energy
 - Water energy → kinetic and heat energy → electric energy
 - Gravitational potential energy → kinetic energy → electric energy
 - Gravitational potential energy → kinetic and heat energy → electric energy
- Answer: d
24. Select a choice that is the best explanation of energy transformation resulting from the coal generating power.
- Heat → mechanical energy → electric energy
 - Heat → kinetic energy → electric and heat energy
 - Heat → kinetic energy → mechanical energy → electric energy
 - Heat → kinetic energy → mechanical energy → electric and heat energy
- Answer: d
25. The nuclear power plant used heat energy to boil water in the core of the reactor. When is the heat energy given off in the nuclear fission reaction?
- Atoms combining
 - Atoms splitting
 - Atoms heating
 - Atoms accelerating
- Answer: b
26. What kind of energy source is the major use of the generation power in Khon Kaen province?
- Hydropower
 - Coal
 - Natural gas
 - Renewable energy sources
- Answer: c
27. What does a kind of the generation power give the least environment damages?
- Solar power plant
 - Wind power plant
 - Coal power plant
 - Nuclear power plant
- Answer: b

28. Why is the Mae moh coal power plant still running although it generates environment problems? Select the best reason that is appropriate for Thailand.

- a) There is increase high demand of electric energy.
- b) There is continually industrial expansion in the Northern part of Thailand.
- c) Scientists can create process of generating power to emit less pollution than before.
- d) Coal is the cheapest energy sources and there is a large amount of it in Thailand.

Answer: d

29. Why does a power plant can never turn all the energy stored in energy sources into electric energy?

- a) There are no efficiency generators.
- b) Energy sources are contaminated.
- c) Waste heat spread out during generating power process.
- d) There are no good technologies.

Answer: c

30. What kind of energy source is the most used in Thailand?

- a) Hydropower
- b) coal
- c) Natural gas
- d) Renewable energy sources

Answer: c

5. The Semantic Differential Scale of Students' Reaction in Energy Unit (SSRE)

Evaluation Sheet of the STS Energy Unit

Name Class School Date

This evaluation sheet seeks your personal opinion and your individual comments about the STS energy unit that you have completed. Your comments will not affect your science score and behavior score. Please, give exactly your ideas. Thank you very much for your good cooperation.

Section 1: Your comments about the classroom activities. The main activities are listed below. Place tick along the scale beside each activity to indicate how you feel about the activity.

The Sub-unit 1 the Use of Energy

Main activities	Your interest								
	1	2	3	4	5	6	7		
1. Make skeptical questions toward the scenario of petrol price	Not interest	Very interest	
2. Discussing for find solution of petrol price	Not interest	1	2	3	4	5	6	7	Very interest
3. Studying of energy forms	Not interest	1	2	3	4	5	6	7	Very interest
4. Studying of energy spreading out	Not interest	1	2	3	4	5	6	7	Very interest
5. Studying of energy transformation and the law of energy conservation (Where is energy gone?)	Not interest	1	2	3	4	5	6	7	Very interest
6. Studying of renewable energy sources	Not interest	1	2	3	4	5	6	7	Very interest
7. Activities for the solutions of the increased petrol price situation	Not interest	1	2	3	4	5	6	7	Very interest

The Sub-unit 2 Generating Power and Use of Electrical Energy

Main activities	Your interest								
1. Make skeptical questions toward the scenario of the Mae moh power plant	Not interest	1	2	3	4	5	6	7	Very interest
2. Discussing for find solution of the situation of the Mae moh power plant	Not interest	1	2	3	4	5	6	7	Very interest
3. Studying of electromagnetic induction from simple generators	Not interest	1	2	3	4	5	6	7	Very interest
4. Study the process of generating power of hydro power plant	Not interest	1	2	3	4	5	6	7	Very interest
5. Study the process of generating power of coal fire power plant	Not interest	1	2	3	4	5	6	7	Very interest
6. Study other processes of generating power	Not interest	1	2	3	4	5	6	7	Very interest
7. The Nam-pong power plant trip	Not interest	1	2	3	4	5	6	7	Very interest
8. Group discussion for finding solutions of situation of the Mae moh power plant under conditions of environment, economic, and society	Not interest	1	2	3	4	5	6	7	Very interest
9. Role-play for finding solutions of situation of the Mae moh power plant	Not interest	1	2	3	4	5	6	7	Very interest

Section 2: Your comments of comparing the STS energy unit to the other science units. This section requires you to compare the STS energy unit to other units that you have covered in science. Please tick a position along the scale after each question to indicate your answer to each of the following questions.

Questions	Your comment								
1. Are classroom activities in the STS energy unit any different from those in your normal science classes?	Just the same	1	2	3	4	5	6	7	Very different
3. Compared to your normal science classes, did you observe any differences in the way the STS Energy unit was taught?	Just the same	1	2	3	4	5	6	7	Very different
3. How would you compare your classroom participation during the STS Energy unit to that in your normal science classes?	Participated less	1	2	3	4	5	6	7	Participated more
4. Compared to your normal science classes, did you feel that this unit gives you learning more or less?	Learning less	1	2	3	4	5	6	7	Learning more
5. Compared to your normal science classes, did you feel that this unit gives you to make sense more or less relationship between science, technology, and society?	Make sense less	1	2	3	4	5	6	7	Make sense more
6. Compared to your normal science classes, how enjoyable did you find in the STS Energy unit?	Less enjoyable	1	2	3	4	5	6	7	More enjoyable
7. Compared to your normal science classes, how interesting did you find in the STS Energy unit?	Less interesting	1	2	3	4	5	6	7	More interesting
8. Compared to your normal science classes, how difficult did you find in the STS Energy unit?	Less difficult	1	2	3	4	5	6	7	More difficult

More comments:

APPENDIX B
STATISTICAL DATA

1. Data from the Students' Responses of the Questionnaires for Exploring Students' Idea about Energy Related Technological and Societal Issues (QSETS)

Appendix Table B1.1 Student Responses on the QSETS Question 1

Q 1: Should Thai government give research money to scientists to study sustainable energy or explore the unknowns of energy resources?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) I don't understand the question.	0	0.0	0	0.0	0	0	0	0.0	0	0.0
(b) I don't know enough about this subject to make a choice.	5	12.2	0	0.0	0	0	2	7.4	7	4.7
Money should be spent on these research:										
(c) So that Thailand does not fall behind other countries and become dependent upon them.	13	31.7	26	61.9	10	26.3	9	33.3	58	39.2
(d) In order to satisfy the human urge to know the unknown: that is, to satisfy scientific curiosity.	14	34.2	3	7.1	6	15.8	5	18.5	28	18.9
(e) Even though it's often impossible to tell ahead of time whether the research will be beneficial or not. It's an investment risk, but we should take it.	2	4.9	6	14.3	13	34.2	2	7.4	23	15.5
(f) Only when the research is obviously useful to society.	1	2.4	1	2.4	5	13.2	5	18.5	12	8.1
Total	30	73.2	36	85.7	34	89.5	21	77.7	121	81.7
Little or no money should be spent on research:										
(g) Because the money could be spent on other things, such as investing for industry or helping Thai's unemployed.	1	2.4	2	4.8	0	0.0	1	3.7	4	2.7
(h) Because the other countries have already done about this kind of research and we can use their results	5	12.2	1	2.4	0	0.0	0	0.0	6	4.1
Total	6	14.6	3	7.2	0	0.0	1	3.7	10	6.8
(i) None of these choices fits my basic viewpoint. My view is	0	0.0	3	7.1	4	10.5	3	11.1	10	6.8

Appendix Table B1.2 Student Responses on the QSETS Question 2

Q 2: A country's politics affect scientists' study of energy. This happens because scientists are not isolated from their society. Do you agree or disagree? Why?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	13	26.5	0	0.0	1	2.6	1	3.7	15	9.6	
(b) I don't know enough about this subject to make a choice.	8	16.3	0	0.0	3	7.9	1	3.7	12	7.7	
I agree:											
(c) Because funding for energy comes mainly from governments which control the way the money is spent. Scientists sometimes have to lobby for funds.	8	16.3	18	42.9	13	34.2	6	22.2	45	28.8	
(d) Because government established the Organization for studying about energy and so there is no need for extra research.	4	8.2	7	16.6	4	10.5	4	14.8	19	12.2	
(e) Because politics limits and controls scientists by telling them what research to do.	3	6.1	1	2.4	1	2.6	3	11.1	8	5.1	
(f) Because governments can force scientists to work on a project which scientists feel is wrong, and not allow the scientists to work on projects beneficial to society.	3	6.1	4	9.5	8	21.1	9	33.3	24	15.4	
(g) Because scientists are a part of society and are affected like everyone else.	2	4.1	2	4.8	5	13.2	3	11.1	12	7.7	
(h) Because scientists try to understand and help society and thus, because of their involvement and importance to society, scientists are closely tied to society.	3	6.1	10	23.8	3	7.9	0	0.0	16	10.3	
Total	23	46.9	42	100.0	34	89.5	25	92.5	124	79.5	
I disagree:											
(i) Because scientific research has nothing to do with politics.	4	8.2	0	0.0	0	0.0	0	0.0	4	2.6	
(j) Because scientists are isolated from their society.	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	
Total	4	8.2	0	0.0	0	0.0	0	0.0	4	2.6	
(k) None of these choices fits my basic viewpoint. My view is	1	2.1	0	0.0	0	0.0	0	0.0	1	0.6	

Appendix Table B1.3 Student Responses on the QSETS Question 3

Q 3: In Thailand, we do not need study research related to energy. We adopt knowledge and technology from other countries such as Japan, USA or Europe. This is useful for our country. Do you agree or disagree? Why?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	2	4.8	0	0.0	0	0.0	1	3.7	3	2.0	
(b) I don't know enough about this subject to make a choice.	1	2.4	0	0.0	0	0.0	1	3.7	2	1.3	
I agree:											
(c) Because we must spend amounts of money but there is sometime nothing that is useful in society.	3	7.1	0	0.0	1	2.6	4	14.8	8	5.4	
(d) Because greater amounts of money should be spent on foundation education, industrial research or community industrial research (One Tumbol One Product).	4	9.5	3	7.1	0	0.0	4	14.8	11	7.4	
(e) Because it is more cost effective. Thailand does not spend any budget for research but we could still use technology that is imported from developed countries.	2	4.8	1	2.4	1	2.6	1	3.7	5	3.4	
Total	9	21.4	4	9.5	2	5.2	9	33.3	24	16.2	
I disagree:											
(f) Because investment for studying research will develop Thai scientists' quality even though sometimes research will fail.	16	38.1	15	35.7	9	23.7	8	29.6	48	32.2	
(g) Because Thailand must import high cost of technology and this upset the balance of import and export trade.	1	2.4	8	19.0	6	15.8	0	0.0	15	10.1	
(h) Because we should develop energy technology stemming from our own requirements and to solve our local problems.	11	26.2	15	35.7	21	55.3	8	29.6	55	36.9	
Total	28	66.7	38	90.4	36	94.8	16	59.2	118	79.2	
(i) None of these choices fits my basic viewpoint. My view is	2	4.8	0	0.0	0	0.0	0	0.0	2	1.3	

Appendix Table B1.4 Student Responses on the QSETS Question 4

Q 4: We have a large amount of sunlight everyday a year in Thailand. Should we develop our knowledge of solar cell technology which could be used to build solar power plant?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	
(b) I don't know enough about this subject to make a choice.	2	4.3	0	0.0	4	10.5	0	0.0	6	3.9	
Yes, we should											
(c) Because solar energy has the least effect on an environment.	2	4.3	1	2.4	2	5.3	1	3.7	6	3.9	
(d) Because solar energy is sustainable energy	9	20.0	5	11.9	4	10.5	5	18.5	23	15.0	
(e) It is worth while in the long run because solar energy is has no cost even though there is a high cost to construct the solar power plant.	13	28.0	26	61.9	20	52.6	11	40.7	70	45.8	
(f) Thailand needs to use large amounts of energy in the future but currently energy resource is restricted.	12	26.0	8	19.0	5	13.2	6	22.2	31	20.3	
Total	36	78.3	40	95.2	31	81.6	23	85.1	130	85.0	
No, we should not											
(g) Because it will take too much time to recover the constructing costs.	4	8.7	1	2.4	0	0.0	3	11.1	8	5.2	
(h) Because Thailand would spend a lot of money for constructing and taking care the power plants, but generate little energy.	3	6.5	1	2.4	2	5.3	1	3.7	7	4.6	
Total	7	15.2	2	4.8	2	5.3	4	14.8	15	9.8	
(i) None of these choices fits my basic viewpoint. My view is	1	2.2	0	0.0	1	2.6	0	0.0	2	1.3	

Appendix Table B1.5 Student Responses on the QSETS Question 5

Q 5: The Mae-moa coal power plant has greatly polluted the air. It is a responsible decision to close down these plants and stop their production. Do you agree or disagree? Why?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	0	0.0	0	0.0	0	0.0	1	3.7	1	0.7	
(b) I don't know enough about this subject to make a choice.	4	9.3	0	0.0	7	18.4	1	3.7	12	8.0	
I agree:											
(c) We should save our country and its future generations.	3	7.0	5	11.9	7	18.4	0	0.0	15	10.0	
(d) Because the government have enough problems without the added problem of pollution.	2	4.7	1	2.4	0	0.0	8	29.6	11	7.3	
(e) Because pollution should be confined as much as possible. Spreading it around would only create more damage.	10	23.3	11	26.2	7	18.4	9	33.3	37	24.7	
Total	15	35.0	17	40.5	14	36.8	17	62.9	63	42.0	
I disagree:											
(f) Because doesn't matter whether we will have the coal power plant if another country still produce pollution. The effects of pollution are global.	1	2.3	5	11.9	3	7.9	1	3.7	10	6.7	
(g) Because the coal power plant is cheap and we have a lot of coal. That means we can gain more profit than other power plants.	3	7.0	5	11.9	2	5.3	1	3.7	11	7.3	
(h) We still hope to use coal for generating power if scientists can create process of generating power to emit less pollution than before.	10	23.3	11	26.2	5	13.2	4	14.8	30	20.0	
(i) The coal power plant produces cheap power plant. This helps the government to decrease the budget.	1	2.3	0	0.0	1	2.6	0	0.0	2	1.3	
(j) It's hard to tell. We would help reduce our own pollution. But our government must make the decision based on economic growth.	6	14.0	4	9.5	4	10.5	1	3.7	15	10.0	
Total	21	48.9	25	59.5	15	39.5	7	25.9	68	45.3	
(k) None of these choices fits my basic viewpoint. My view is	3	7.0	0	0.0	2	5.3	1	3.7	6	4.0	

Appendix Table B1.6 Student Responses on the QSETS Question 6

Q 6: Because scientists and engineers are the people who know the facts best, they should be the ones to decide what types of energy Thailand will use in the future (for example, nuclear, hydro, solar, or coal burning). Do you agree or disagree? Why?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) I don't understand the question.	0	0.0	0	0.0	0	0.0	2	7.4	2	1.4
(b) I don't know enough about this subject to make a choice.	2	5.9	0	0.0	2	5.3	3	11.1	7	5.0
I agree:										
(c) Because they have the training and facts which give them a better understanding of the issue.	3	8.8	2	4.8	2	5.3	9	33.3	16	11.3
(d) Because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.	2	5.9	3	7.1	1	2.6	1	3.7	7	5.0
(e) Because they have the training and facts which give them a better understanding; but the public should be involved - either informed or consulted.	12	35.3	11	26.2	11	28.9	5	18.5	39	27.7
Total	17	50	16	38.1	14	36.8	15	55.5	62	44.0
I disagree:										
(f) The decision should be made equally; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society.	9	26.5	18	42.9	17	44.7	4	14.8	48	34.0
(g) The government should decide because the issue is basically a political one; but scientists and engineers should give advice.	4	11.8	0	0.0	2	5.3	0	0.0	6	4.2
(h) The public should decide because the decision affects everyone; but scientists and engineers should give advice.	1	2.9	3	7.1	3	7.9	1	3.7	8	5.7
(i) The public should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.	1	2.9	5	11.9	0	0.0	2	7.4	8	5.7
Total	15	44.1	26	61.9	22	57.9	7	25.9	70	49.6
(j) None of these choices fits my basic viewpoint. My view is	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix Table B1.7 Student Responses on the QSETS Question 7

Q 7: Knowledge and understanding about the science and technology of energy can help people make some moral decisions about generating power. Do you agree or disagree? Why?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) I don't understand the question.	6	13.0	1	2.4	0	0.0	0	0.0	7	4.7
(b) I don't know enough about this subject to make a choice.	2	4.4	0	0.0	3	7.9	1	3.7	6	4.0
I agree. Because energy science knowledge can help you make some decisions:										
(c) By making you more informed about technology and its effect in the environment. This background information can help you cope with the moral aspects of environment.	20	43.5	15	35.7	10	26.3	13	48.1	58	38.7
(d) By providing background information; but moral decisions must be made by individuals.	7	15.2	9	21.4	10	26.3	7	25.9	33	22.0
Total	27	58.7	24	57.1	20	52.6	20	74.0	91	60.7
I disagree: Energy science knowledge and technology cannot help you make moral decisions:										
(e) Because energy science knowledge and technology have nothing to do with moral decisions. What people do with the results is not the scientist's concern.	7	15.2	11	26.2	4	10.5	5	18.5	27	18.0
(f) Because moral decisions are made solely on the basis of an individual's values and beliefs.	3	6.5	6	14.3	8	21.1	0	0.0	17	11.3
Total	10	21.7	17	40.5	12	31.6	5	18.5	44	29.3
(g) None of these choices fits my basic viewpoint. My view is	1	2.2	0	0.0	0	0.0	1	3.7	2	1.3

Appendix Table B1.8 Student Responses on the QSETS Question 8

Q 8: There have been protests against the use of coal, nuclear energy and dams for power generation because of worried about pollution, safety in process of generating power or using land. Energy science and technology knowledge offer a great deal of help in resolving these social problems. Do you agree or disagree? Why?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	3	6.7	0	0.0	2	5.3	0	0.0	5	3.3	
(b) I don't know enough about this subject to make a choice.	3	6.7	0	0.0	4	10.5	1	3.7	8	5.2	
I agree.											
(c) Energy science knowledge and technology can certainly help to resolve these problems. The problems could use new ideas from energy science knowledge and new inventions from technology.	20	44.4	12	28.6	8	21.1	12	44.4	52	34.2	
(d) Science and technology can help resolve some social problems but not others.	13	28.9	22	52.4	17	44.7	10	37.0	62	40.8	
Total	33	73.3	34	81.0	25	65.8	22	81.4	114	75.0	
I disagree:											
(e) It's not question of energy science knowledge and technology helping, but rather it is question of people using science and technology wisely and carefully.	4	8.9	3	7.1	3	7.9	0	0.0	10	6.6	
(f) It is hard to see how energy science knowledge and technology could help very much in resolving these problems. Social problems concerned human centred.	1	2.2	4	9.5	2	5.3	3	11.1	10	6.6	
(g) Science and technology only make social problem worse. It is the price we pay for advances in science and technology.	1	2.2	1	2.4	1	2.6	1	3.7			
Total	6	13.3	8	19.0	6	15.8	4	14.8	24	15.8	
(h) None of these choices fits my basic viewpoint. My view is	0	0.0	0	0.0	1	2.6	0	0.0	1	0.7	

Appendix Table B1.9 Student responses on the QSETS question 9

Q 9: In your everyday life, knowledge of energy science and technology can help you to manage how to save energy in your house. Do you agree or disagree? Why?											
	School A		School B		School C		School D		Total		
	f	%	f	%	f	%	f	%	f	%	
(a) I don't understand the question.	1	2.4	0	0.0	0	0.0	0	0.0	1	0.7	
(b) I don't know enough about this subject to make a choice.	1	2.4	0	0.0	1	2.6	0	0.0	2	1.3	
I agree.											
(c) I would like to save energy because I know that although energy cannot be lost and destroyed but it is transformed into useful form.	14	33.3	12	28.6	9	23.7	11	40.7	46	30.9	
(d) I iron many clothes in the same time. I think that more electric energy will be conserved by ironing many clothes at the same time, then heating the iron for many garments at a time.	5	11.9	7	16.7	8	21.1	6	22.2	26	17.5	
(e) I do not place hot food into the refrigerator because I understand that the refrigerator must use amount of energy for cooling food.	1	2.4	1	2.4	5	13.2	2	7.4	9	6.0	
(f) The knowledge of losing energy or any knowledge of energy science and technology makes me want to create an electrical device for saving energy.	2	4.8	7	16.7	4	10.5	1	3.7	14	9.4	
(g) I would like to save energy because I know whenever energy is used; energy will be transform into less useful and hard to reuse form.	12	28.5	12	28.6	9	23.7	5	18.5	38	25.5	
Total	34	80.9	39	93.0	35	92.2	25	92.5	133	89.3	
I disagree:											
(h) Because what I learn in classroom is not enough for managing to save energy.	3	7.1	0	0.0	1	2.6	2	7.4	6	4.0	
(i) Although I understand knowledge, I cannot to force others to save energy, because management to save energy may disturb daily individual habits.	2	4.8	3	7.1	1	2.6	0	0.0	6	4.0	
(j) I cannot manage to save energy. I think that only scientists or engineers can do safely and efficiently this work.	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	
Total	5	11.9	3	7.1	2	5.2	2	7.4	12	8.0	
(k) None of these choices fits my basic viewpoint. My view is	1	2.4	0	0.0	0	0.0	0	0.0	1	0.7	

Appendix Table B1.10 Student responses on the QSETS question 10

Q 10: Do you think Thailand should construct more power stations? Why?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) I don't understand the question.	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
(b) I don't know enough about this subject to make a choice.	3	7.3	0	0.0	2	5.3	2	7.4	7	4.7
Yes, we should because:										
(c) We have no choice. Because we consume increasing amounts of energy, we must construct power stations.	1	2.5	1	2.4	0	0.0	1	3.7	3	2.0
(d) We need to reserve energy for future use, although we have enough electrical energy at present.	11	26.8	11	26.2	6	15.8	6	22.2	34	23.0
(e) At the present, we do not have enough electrical energy, so we must buy it from other countries.	5	12.2	2	4.8	2	5.3	4	14.8	13	8.8
(f) Electrical energy is a part of our life. Without it we cannot function in everyday life; we cannot cook, watch television, or use the internet etc.	5	12.2	5	11.9	2	5.3	7	25.9	19	12.8
Total	22	53.7	19	45.3	10	26.4	18	66.6	69	46.6
No, we should not because:										
(g) We feel we do have enough energy. We should save energy rather than plan to construct a new power plant.	10	24.4	12	28.6	13	34.2	6	22.2	41	27.7
(h) Constructing a power station usually generates social problems such as pollution. We should decrease electrical energy use in order to decrease other problems and decrease the budget which is needed.	3	7.3	6	14.3	3	7.9	0	0.0	12	8.1
(i) We should be decrease energy use for energy saving and no constructing power plant more.	3	7.3	3	7.1	10	26.3	1	3.7	17	11.5
Total	16	39.0	21	50.0	26	68.4	7	25.9	70	47.3
(j) None of these choices fits my basic viewpoint. My view point is _____	0	0.0	2	4.8	0	0.0	0	0.0	2	1.4

Appendix Table B1.11 Student responses on the QSETS question 11

Q 11: Do you think we use too much energy? Why?										
	School A		School B		School C		School D		Total	
	f	%	f	%	f	%	f	%	f	%
(a) I don't understand the question.	1	2.2	0	0.0	0	0.0	0	0.0	1	0.7
(b) I don't know enough about this subject to make a choice.	1	2.2	0	0.0	1	2.6	1	3.7	3	2.0
Yes, I think so because:										
(c) I think that we don't need to turn on the lamp on day time but most people usually do that.	5	11.1	3	7.1	6	15.8	7	25.9	21	13.8
(d) I think that most people perceive that energy is public property therefore they don't need to save energy.	5	11.1	8	19.0	9	23.7	4	14.8	26	17.1
(e) I think that most people don't care about the difficulty of generating energy therefore they aren't aware of the need to save energy.	18	40.0	17	40.5	9	23.7	10	37.0	54	35.5
(f) I think that people don't pay attention to the fact that increased consumption of energy has caused environmental damage.	6	13.3	4	9.5	8	21.1	3	11.0	21	13.8
(g) I think that people don't see the need for using sustainable energy.	7	15.7	6	14.3	4	10.5	0	0.0	17	11.2
Total	41	91.2	38	90.4	36	94.8	24	88.7	139	91.4
No, I don't think so because:										
(h) I think that people have to pay money for their own energy use. They can use energy as much as they can afford.	1	2.2	2	4.8	1	2.6	0	0.0	4	2.6
(i) I think that energy will never run out. We can create another method for generating power if the present energy resource runs out.	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
(j) I think that I perform only a small act of energy use; therefore it does not affect energy use in the whole country.	0	0.0	1	2.4	0	0.0	1	3.7	2	1.3
Total	1	2.2	3	7.2	1	2.6	1	3.7	6	3.9
(k) None of these choices fits my basic viewpoint. My view is	1	2.2	1	2.4	0	0.0	1	3.7	3	2.0

2. Data from the Students' Responses of the Semantic Differential Scale of Students' Reaction in Energy Unit (SSRE)

Appendix Table B2.1 the Ratings for the Sub-unit 1 Given by the School B Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of petrol price	0	1	2	12	5	6	9
2. Discussing for find solution of petrol price	0	1	0	10	11	7	6
3. Studying of energy forms	0	0	4	11	8	4	8
4. Studying of energy spreading out	0	0	2	8	6	8	10
5. Studying of energy transformation and the law of energy conservation (Where is energy gone?)	0	1	2	4	6	7	15
6. Studying of renewable energy sources	0	0	0	3	9	12	11
7. Activities for the solutions of the increased petrol price situation	0	1	1	4	8	12	9

Appendix Table B2.2 the Ratings for the Sub-unit 2 Given by the School B Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of the Mae moh power plant	0	2	0	7	10	7	9
2. Discussing for find solution of the situation of the Mae moh power plant	0	1	2	8	7	10	7
3. Studying of electromagnetic induction from simple generators	0	0	1	6	11	11	6
4. Study the process of generating power of hydro power plant	0	0	1	3	7	6	18
5. Study the process of generating power of coal fire power plant	0	0	1	5	8	10	11
6. Study other processes of generating power	0	0	2	9	4	8	12
7. The Nam-pong power plant trip	0	0	0	3	6	9	17
8. Group discussion for finding solutions of situation of the Mae moh power plant under conditions of environment, economic, and society	0	1	0	6	11	10	7
9. Role-play for finding solutions of situation of the Mae moh power plant	1	0	4	5	9	5	11

Appendix Table B2.3 the Ratings for Comparison of the STS Energy Unit and Other Science Unit Given by the School B Students

Questions	Comment						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Are classroom activities in the STS energy unit any different from those in your normal science classes?	0	3	1	6	11	9	5
3. Compared to your normal science classes, did you observe any differences in the way the STS Energy unit was taught?	0	0	3	5	11	5	11
3. How would you compare your classroom participation during the STS Energy unit to that in your normal science classes?	1	2	1	4	7	10	10
4. Compared to your normal science classes, did you feel that this unit gives you learning more or less?	3	0	2	10	5	9	6
5. Compared to your normal science classes, did you feel that this unit gives you to make sense more or less relationship between science, technology, and society?	2	0	1	8	9	10	5
6. Compared to your normal science classes, how enjoyable did you find in the STS Energy unit?	1	0	3	7	8	10	6
7. Compared to your normal science classes, how interesting did you find in the STS Energy unit?	2	2	2	5	8	11	5
8. Compared to your normal science classes, how difficult did you find in the STS Energy unit?	5	1	3	9	6	8	3

Appendix Table B2.4 the Ratings for the Sub-unit 1 Given by the School C Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of petrol price	0	2	6	17	15	5	2
2. Discussing for find solution of petrol price	0	2	8	8	16	11	2
3. Studying of energy forms	1	0	8	13	12	10	2
4. Studying of energy spreading out	0	1	6	18	14	7	1
5. Studying of energy transformation and the law of energy conservation (Where is energy gone?)	1	2	7	12	17	5	3
6. Studying of renewable energy sources	0	0	3	12	18	9	5
7. Activities for the solutions of the increased petrol price situation	1	1	4	10	12	13	6

Appendix Table B2.5 the Ratings for the Sub-unit 2 Given by the School C Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of the Mae moh power plant	1	0	4	8	8	16	10
2. Discussing for find solution of the situation of the Mae moh power plant	1	0	2	10	15	13	6
3. Studying of electromagnetic induction from simple generators	0	2	5	11	16	10	3
4. Study the process of generating power of hydro power plant	0	0	3	10	12	15	7
5. Study the process of generating power of coal fire power plant	0	0	7	6	17	13	4
6. Study other processes of generating power	0	0	5	14	15	10	3
7. The Nam-pong power plant trip	0	1	1	7	4	8	26
8. Group discussion for finding solutions of situation of the Mae moh power plant under conditions of environment, economic, and society	0	1	2	10	13	11	10
9. Role-play for finding solutions of situation of the Mae moh power plant	0	1	3	4	7	9	23

Appendix Table B2.6 the Ratings for Comparison of the STS Energy Unit and Other Science Unit Given by the School C Students

Questions	Comment						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Are classroom activities in the STS energy unit any different from those in your normal science classes?	1	2	5	11	11	13	4
3. Compared to your normal science classes, did you observe any differences in the way the STS Energy unit was taught?	1	3	5	11	12	8	7
3. How would you compare your classroom participation during the STS Energy unit to that in your normal science classes?	0	1	3	7	17	11	8
4. Compared to your normal science classes, did you feel that this unit gives you learning more or less?	1	0	2	17	9	13	5
5. Compared to your normal science classes, did you feel that this unit gives you to make sense more or less relationship between science, technology, and society?	1	0	1	15	17	9	4
6. Compared to your normal science classes, how enjoyable did you find in the STS Energy unit?	1	0	7	5	13	12	9
7. Compared to your normal science classes, how interesting did you find in the STS Energy unit?	1	0	5	12	11	6	12
8. Compared to your normal science classes, how difficult did you find in the STS Energy unit?	1	2	4	15	14	8	3

Appendix Table B2.7 the Ratings for the Sub-unit 1 Given by the School D Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of petrol price	0	0	3	8	8	4	5
2. Discussing for find solution of petrol price	0	0	4	7	4	11	2
3. Studying of energy forms	0	0	4	5	8	4	7
4. Studying of energy spreading out	0	1	4	4	8	7	4
5. Studying of energy transformation and the law of energy conservation (Where is energy gone?)	0	0	3	5	8	6	6
6. Studying of renewable energy sources	0	0	3	5	3	7	10
7. Activities for the solutions of the increased petrol price situation	0	0	0	4	6	5	13

Appendix Table B2.8 the Ratings for the Sub-unit 2 Given by the School D Students

Activities	Interest						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Make skeptical questions toward the scenario of the Mae moh power plant	0	0	2	7	5	4	10
2. Discussing for find solution of the situation of the Mae moh power plant	0	0	3	6	7	3	9
3. Studying of electromagnetic induction from simple generators	0	0	4	1	10	6	6
4. Study the process of generating power of hydro power plant	0	0	3	4	7	8	6
5. Study the process of generating power of coal fire power plant	0	0	0	6	10	8	4
6. Study other processes of generating power	0	0	2	6	8	6	6
7. The Nam-pong power plant trip	0	1	1	2	5	2	16
8. Group discussion for finding solutions of situation of the Mae moh power plant under conditions of environment, economic, and society	0	0	0	6	4	10	8
9. Role-play for finding solutions of situation of the Mae moh power plant	0	0	3	5	4	6	9

Appendix Table B2.9 the Ratings for Comparison of the STS Energy Unit and Other Science Unit Given by the School D Students

Questions	Comment						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1. Are classroom activities in the STS energy unit any different from those in your normal science classes?	0	0	2	6	8	6	6
3. Compared to your normal science classes, did you observe any differences in the way the STS Energy unit was taught?	2	0	6	4	4	6	8
3. How would you compare your classroom participation during the STS Energy unit to that in your normal science classes?	0	0	5	6	5	8	4
4. Compared to your normal science classes, did you feel that this unit gives you learning more or less?	0	0	1	7	10	7	3
5. Compared to your normal science classes, did you feel that this unit gives you to make sense more or less relationship between science, technology, and society?	0	0	3	4	5	9	7
6. Compared to your normal science classes, how enjoyable did you find in the STS Energy unit?	0	0	3	5	2	11	7
7. Compared to your normal science classes, how interesting did you find in the STS Energy unit?	0	1	2	2	7	10	6
8. Compared to your normal science classes, how difficult did you find in the STS Energy unit?	1	1	2	7	5	4	8

3. Data from the Students' Responses of the Energy Test

Appendix Table B3.1 Students' Responses Energy Test in the Question 1

1. What main of forms are given by battery? (Answer: a)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Chemical potential and electric energy	23	48.9	40	81.6	37	78.7	13	44.9
b) Radiant and electric energy	5	10.6	0	0.0	3	6.4	9	31.0
c) Gravitational potential and electric energy	1	2.1	0	0.0	0	0.0	1	3.4
d) Magnetic and electric energy	18	38.3	9	18.4	7	14.9	6	20.7
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.2 Students' Responses Energy Test in the Question 2

2. What does form of energy result when protons and neutrons are arranged into atomic nuclei? (Answer: b)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Radiant energy	2	4.3	3	6.1	0	0.0	4	13.8
b) Nuclear energy	40	85.1	40	81.6	47	100.0	15	51.7
c) Electric energy	2	4.3	4	8.2	0	0.0	6	20.7
d) Chemical energy	3	6.4	2	4.1	0	0.0	4	13.8
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.3 Students' Responses Energy Test in the Question 3

3. Select choice that does not give the kinetic energy. (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Molecular of air	6	12.8	0	0.0	0	0.0	1	3.4	
b) A pen is placed on the table	28	59.6	38	77.6	31	66.0	13	44.9	
c) Light	7	14.9	9	18.4	8	17.0	10	34.5	
d) A car is moving	6	12.8	2	4.1	8	17.0	5	17.2	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.4 Students' Responses Energy Test in the Question 4

4. What form of energy does water reservoir has? (Answer: c)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Kinetic energy	10	21.3	5	10.2	7	14.9	2	6.9	
b) Electric energy	16	34.0	6	12.2	9	19.1	9	31.0	
c) Gravitational potential energy	11	23.4	18	36.7	14	29.8	5	17.2	
d) Water energy	10	21.3	20	40.8	17	36.2	13	44.9	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.5 Students' Responses Energy Test in the Question 5

5. When you walk up stair, you increase your gravitational energy. This energy must come from somewhere. Where did it come from?(Answer: c)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Kinetic energy	12	25.5	27	55.1	28	59.6	17	58.7	
b) Heat energy	3	6.4	1	2.0	1	2.1	1	3.4	
c) Chemical potential energy	12	25.5	12	24.5	11	23.4	2	6.9	
d) Elastic potential energy	20	42.6	9	18.4	7	14.9	9	31.0	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.6 Students' Responses Energy Test in the Question 6

6. Select choice that is renewable energy source. (Answer: d)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Coal	10	21.3	1	2.0	0	0.0	3	10.3	
b) Natural gas	14	29.8	11	22.4	4	8.5	11	37.9	
c) Nuclear energy sources	6	12.8	5	10.2	3	6.4	2	6.9	
d) Water energy sources	17	36.2	32	65.3	40	85.1	13	44.9	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.7 Students' Responses Energy Test in the Question 7

7. Biogas is one of renewable energy sources that resulting from manure and organic matter are left to rot in a closed tank. What gas is given off? (Answer: a)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Methane	20	42.6	28	2.0	30	63.8	7	24.1	
b) Propane	8	17.0	5	57.1	3	6.4	2	6.9	
c) NGV	16	34.0	11	10.2	7	14.9	14	48.3	
d) Gasohol	3	6.4	4	8.2	7	14.9	6	20.7	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.8 Students' Responses Energy Test in the Question 8

8. The prices of fossil petrol rise substantially. It might be time for use renewable energy. What kind of renewable energy would be used urgently in Thailand? Why? (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Use light energy because solar car can be driven without petrol.	14	29.8	5	10.2	1	2.1	7	24.1	
b) Use biomass because Thailand has amount of crop that is fermented to give alcohol, which is used as a fuel.	17	36.2	22	44.9	41	87.2	14	48.3	
c) Use NGV gas because Thailand has sources of NGV gas. This means that it gives the lower cost of energy than petrol.	14	29.8	19	38.8	3	6.4	6	20.7	
d) Use electric energy because electric car can be driven without petrol.	2	4.3	3	6.1	2	4.3	2	6.9	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.9 Students' Responses Energy Test in the Question 9

9. Select the best reason why the solar energy should be used in Thailand. (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) There are three seasons in Thailand.	1	2.1	0	0.0	3	6.4	4	13.8	
b) There is a large amount of sunlight everyday a year in Thailand.	43	91.5	45	91.8	39	83.0	24	82.8	
c) There is a short rainy season in Thailand.	1	2.1	3	6.2	5	10.6	1	3.4	
d) There is a long winter season in Thailand.	2	4.3	1	2.0	0	0.0	0	0.0	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.10 Students' Responses Energy Test in the Question 10

10. Select below an activity that is the most consuming energy from petrol. (Answer: a)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Transportation	28	59.6	32	65.3	22	46.8	8	27.6	
b) Agriculture	0	0.0	0	0.0	1	2.1	1	3.4	
c) Industry	9	19.1	4	8.2	5	10.6	2	6.9	
d) Generating power	10	21.3	13	26.5	19	40.5	18	62.1	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.11 Students' Responses Energy Test in the Question 11

11. What is energy the resulting from the ability of to do some kinds of work? (Answer: a)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Potential energy	7	14.9	10	20.4	7	14.9	2	6.9	
b) Kinetic energy	7	14.9	6	12.2	5	10.6	5	17.2	
c) Mechanical energy	33	70.2	32	65.4	36	74.5	19	65.6	
d) Nuclear energy	0	0.0	1	2.0	0	0.0	3	10.3	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.12 Students' Responses Energy Test in the Question 12

12. The scientific knowledge stated that "the total of energy always stays the same", so why people need to save energy. Which scientific idea about energy does explain this argument? (Answer: d)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Because although energy stays the same, people should save energy for use in the long run.	7	14.9	8	16.3	10	21.3	5	17.2	
b) Because shortage of budget. Energy saving is budget saving.	10	21.3	0	0.0	1	2.1	4	13.8	
c) Because energy might run out in the future.	10	21.3	7	14.3	16	34.0	8	27.6	
d) Because energy can be transformed into non-useful forms of energy (e.g. waste heat).	20	42.6	34	69.4	20	42.6	12	41.4	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.13 Students' Responses Energy Test in the Question 13

13. Which one is the nature of energy that affects energy use? (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Energy can be transformed from one form to other forms of energy.	10	21.3	5	10.2	3	6.4	3	10.3	
b) All of energy in its sources can never be used.	10	21.3	14	28.6	12	25.5	5	17.3	
c) Energy use always gives pollutions.	6	12.8	1	2.0	4	8.5	3	10.3	
d) Energy sources cannot be replaced when energy are used.	21	44.7	29	59.4	28	59.6	18	62.1	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.14 Students' Responses Energy Test in the Question 14

14. What are the three main forms of energy resulting from turning on the television? (Answer: c)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Heat, mechanical, and light energy	7	14.9	6	12.2	6	12.8	4	13.8	
b) Mechanical, heat, and sound energy	9	19.1	4	8.2	6	12.8	2	6.9	
c) Heat, sound, and light energy	30	63.8	17	34.7	18	38.3	18	62.1	
d) Mechanical, sound and wave energy	1	2.1	22	44.9	17	36.1	5	17.2	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.15 Students' Responses Energy Test in the Question 15

15. While Daeng is ironing her shirts, she thinks of her scientific knowledge that she just learn from school. She told her mother that all of electric energy flowing in the iron would not be transformed to heat of iron. What the scientific knowledge is Daeng considering? (Answer: c)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) The law of energy conservation	7	14.9	5	10.2	1	2.1	3	10.3	
b) Energy transformation	18	38.3	25	51.0	26	55.4	16	55.2	
c) The second law of thermodynamics	12	25.5	16	32.7	12	25.5	4	13.8	
d) Heat conduction	10	21.3	3	6.1	8	17.0	6	20.7	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.16 Students' Responses Energy Test in the Question 16

16. Which two of the four following situations are examples of law of conservation energy?

1. Dum has changed the incandescent bulbs to energy-saving fluorescent tubes. He has found them cheaper in the long run as they last longer and they are much brighter.
2. Ann touches the back of a fan. She found that it is hot. So, she understands that input energy (electric energy) has been transformed into kinetic energy of the fan and heat energy in the motor.
3. Daeng's family switch off the lights and all electrical points when no one is in the room, such as television and the computer, before going to the bed every night. Leaving them on stand by mode will still use up energy.
4. The officer of the Num-pong steam power plant explains to students that the power plant uses high pressure steam at 500 C° as the force for turning the turbine. The turbine then turns the electric generator. This process provides electricity, but it is not 100 percent of input energy. The remaining input energy is transformed in to thermal energy of the low pressure water and heat of the turbine. (Answer: c)

Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) 1, 2	1	2.1	0	0.0	2	4.3	0	0.0
b) 3, 4	11	23.4	8	16.3	11	23.4	6	20.7
c) 2, 4	10	21.3	4	8.2	7	14.9	7	24.1
d) 1, 3	25	53.2	37	75.5	27	57.4	16	55.2
Total	47	100.0		100.0	47	100.0	29	100.0

Appendix Table B3.17 Students' Responses Energy Test in the Question 17

17. "Energy is transformed from one form to another form but the total amount of amount of energy stays the same." What is this scientific concept? (Answer: a)

Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) The law of energy conservation	10	21.3	7	14.3	11	23.4	4	13.8
b) Energy transformation	25	53.2	18	36.7	19	40.5	16	55.2
c) Entropy	7	14.9	4	8.2	9	19.1	2	6.9
d) The law of nature of energy	5	10.6	20	40.8	8	17.0	7	24.1
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.18 Students' Responses Energy Test in the Question 18

18. Electric energy is used to power a lamp. Select the statements that are true. (Answer: b)

Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) The amount of light energy produced more than the amount of electrical energy used.	8	17.0	11	22.4	14	29.8	4	13.8
b) The amount of light energy produced less than the amount of electrical energy used.	16	34.0	11	22.4	11	23.4	5	17.2
c) The amount of light energy produced the same as the amount of electrical energy used.	7	14.9	7	14.3	10	21.3	8	27.6
d) The amount of light energy produced less than or the same as the amount of electrical energy used.	16	34.0	20	40.8	12	25.5	12	41.4
Total	47	100	49	100	47	100	29	100

Appendix Table B3.19 Students' Responses Energy Test in the Question 19

19. What are the most two devices to induce electric current? (Answer: b)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Ammeter and wires	4	8.5	1	2.0	0	0.0	2	6.9
b) Coil and magnetic	31	66.0	44	89.8	47	100.0	19	65.6
c) Coil and wires	8	17.0	3	6.2	0	0.0	5	17.2
d) Ammeter and magnetic	4	8.5	1	2.0	0	0.0	3	10.3
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.20 Students' Responses Energy Test in the Question 20

20. Select the most important factor to generating power. (Answer: a)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) A number of copper coil	29	61.7	26	53.1	42	89.4	22	76.0
b) Velocity of turbine	9	19.1	22	44.9	5	10.6	1	3.4
c) Direction of magnetic field	8	17.0	1	2.0	0	0.0	5	17.2
d) Direction of turbine turning	1	2.1	0	0.0	0	0.0	1	3.4
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.21 Students' Responses Energy Test in the Question 21

21. The Mae Moh released the serious level of air pollution in 1992 and 1999. That situation hurt a number of people, and destroyed crop plant and cattle. What is kind of gas emitted? (Answer: b)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Carbon dioxide	7	14.9	0	0.0	1	2.1	4	13.8
b) Sulfur dioxide	26	55.3	46	93.9	45	95.8	19	65.5
c) Carbon monoxide	10	21.3	2	4.1	0	0.0	2	6.9
d) Sulfur monoxide	4	8.5	1	2.0	1	2.1	4	13.8
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.22 Students' Responses Energy Test in the Question 22

22. Select the statement that is not effect of air pollution that released from the Mae moh power plant. (Answer: a)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Increased the PH value of soil and water.	17	36.2	20	40.9	18	38.3	12	41.4
b) People sick as the Numoconiosease.	3	6.4	1	2.0	0	0.0	2	6.9
c) Acid rain speeds up the corrosion of metals.	11	23.4	1	2.0	8	17.0	7	24.1
d) The water reservoir becomes contaminated with dissolved metals.	16	34.0	27	55.1	21	44.7	8	27.6
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.23 Students' Responses Energy Test in the Question 23

23. Select a choice that is the best explanation of energy transformation resulting from the hydro generating power. (Answer: d)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Water energy → electric energy	3	6.4	3	6.1	0	0.0	1	3.4	
b) Water energy → kinetic and heat energy → electric energy	19	40.4	19	38.8	16	34.0	18	62.2	
c) Gravitational potential energy → kinetic energy → electric energy	11	23.4	16	32.7	8	17.0	5	17.2	
d) Gravitational potential energy → kinetic and heat energy → electric energy	14	29.8	11	22.4	23	49.0	5	17.2	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.24 Students' Responses Energy Test in the Question 24

24. Select a choice that is the best explanation of energy transformation resulting from the coal generating power. (Answer: d)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Heat → mechanical energy → electric energy	9	19.1	5	10.2	2	4.3	5	17.2	
b) Heat → kinetic energy → electric and heat energy	8	17.0	8	16.3	3	6.4	5	17.2	
c) Heat → kinetic energy → mechanical energy → electric energy	15	31.9	24	49.0	35	74.4	9	31.1	
d) Heat → kinetic energy → mechanical energy → electric and heat energy	15	31.9	12	24.5	7	14.9	10	34.5	
Total	47	100.0	49	100.0	47	100.0		100.0	

Appendix Table B3.25 Students' Responses Energy Test in the Question 25

25. The nuclear power plant used heat energy to boil water in the core of the reactor. When is the heat energy given off in the nuclear fission reaction? (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Atoms combining	12	25.5	5	10.2	14	29.8	3	10.3	
b) Atoms splitting	21	44.7	11	22.4	31	66.0	12	41.4	
c) Atoms heating	9	19.1	13	26.5	1	2.1	4	13.8	
d) Atoms accelerating	5	10.6	20	40.9	1	2.1	10	34.5	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.26 Students' Responses Energy Test in the Question 26

26. What kind of energy source is the major use of the generation power in Khon Kaen province? (Answer: c)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Hydropower	36	76.6	6	12.2	12	25.5	11	37.9	
b) Coal	2	4.3	2	4.1	1	2.1	1	3.4	
c) Natural gas	5	10.6	39	79.6	32	68.1	15	51.8	
d) Renewable energy sources	4	8.5	2	4.1	2	4.3	2	6.9	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.27 Students' Responses Energy Test in the Question 27

27. What does a kind of the generation power give the least environment damages? (Answer: b)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) Solar power plant	21	44.7	27	55.1	27	57.4	19	65.5	
b) Wind power plant	22	46.8	20	40.8	19	40.5	6	20.7	
c) Coal power plant	1	2.1	2	4.1	0	0.0	2	6.9	
d) Nuclear power plant	3	6.4	0	0.0	1	2.1	2	6.9	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.28 Students' Responses Energy Test in the Question 28

28. Why is the Mae moh coal power plant still running although it generates environment problems? Select the best reason that is appropriate for Thailand. (Answer: d)									
Choices	School A		School B		School C		School D		
	f	%	f	%	f	%	f	%	
a) There is increase high demand of electric energy.	29	61.7	33	67.3	25	53.2	9	31.1	
b) There is continually industrial expansion in the Northern part of Thailand.	6	12.8	5	10.2	4	8.6	6	20.7	
c) Scientists can create process of generating power to emit less pollution than before.	6	12.8	4	8.2	9	19.1	7	24.1	
d) Coal is the cheapest energy sources and there is a large amount of it in Thailand.	6	12.8	7	14.3	9	19.1	7	24.1	
Total	47	100.0	49	100.0	47	100.0	29	100.0	

Appendix Table B3.29 Students' Responses Energy Test in the Question 29

29. Why does a power plant can never turn all the energy stored in energy sources into electric energy? (Answer: c)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) There are no efficiency generators.	3	6.4	0	0.0	1	2.1	4	13.8
b) Energy sources are contaminated.	8	17.0	3	6.1	7	14.9	8	27.6
c) Waste heat spread out during generating power process.	28	59.8	39	79.6	35	74.5	12	41.4
d) There are no good technologies.	8	17.0	7	14.3	4	8.5	5	17.2
Total	47	100.0	49	100.0	47	100.0	29	100.0

Appendix Table B3.30 Students' Responses Energy Test in the Question 30

30. What kind of energy source is the most used in Thailand? (Answer: c)								
Choices	School A		School B		School C		School D	
	f	%	f	%	f	%	f	%
a) Hydropower	18	38.3	20	40.9	18	38.3	8	27.6
b) Coal	14	29.8	17	34.7	14	29.8	7	24.1
c) Natural gas	13	27.7	11	22.4	10	21.3	9	31.1
d) Renewable energy sources	2	4.3	1	2.0	5	10.6	5	17.2
Total	47	100.0	49	100.0	47	100.0	29	100.0

4. Statistical Data of Orientations of Students' Posing Questions in the Identification of Social Issues Stage.

Appendix Table B4.1 the Orientations of School B Students' Posing Questions in the Identification of Social Issues Stage of the Sub-unit 1 and 2

Orientation	Sub-unit 1		Sub-unit 2	
	Frequency	Percent	Frequency	Percent
Phenomenon	6	20.00	5	13.89
Hazard	10	33.33	14	38.89
Solution	14	46.67	17	47.22
Total	30	100.00	36	100.00

Appendix Table B4.2 the Orientations of School C Students' Posing Questions in the Identification of Social Issues Stage of the Sub-unit 1 and 2

Orientation	Sub-unit 1		Sub-unit 2	
	Frequency	Percent	Frequency	Percent
Phenomenon	28	65.12	26	40.62
Hazard	7	16.28	14	21.88
Solution	8	18.60	24	37.50
Total	43	100.00	64	100.00

Appendix Table B4.3 the Orientations of School D Students' Posing Questions in the Identification of Social Issues Stage of the Sub-unit 1 and 2

Orientation	Sub-unit 1		Sub-unit 2	
	Frequency	Percent	Frequency	Percent
Phenomenon	21	63.64	14	34.15
Hazard	10	30.30	13	31.70
Solution	2	6.06	14	34.15
Total	33	100.00	41	100.00

BIOGRAPHICAL DATA

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